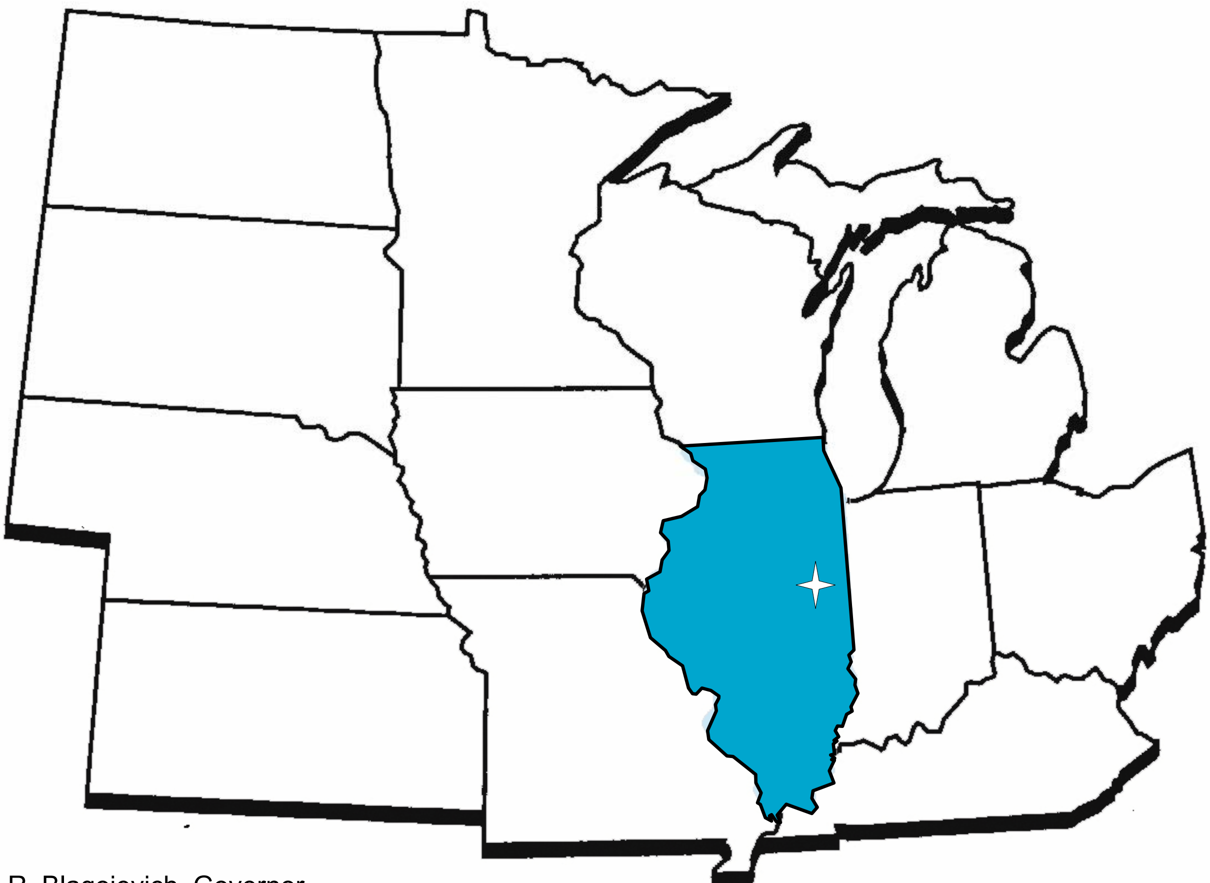
Program with Abstracts

50th Annual Midwest Ground Water Conference

November 1-3, 2005



Rod R. Blagojevich, Governor

Illinois Department of Natural Resources
Joel Brunsvold, Director

Illinois State Geological Survey
William W. Shilts, Chief

Illinois State Geological Survey OFS 2005-13

50th Annual

Midwest Ground Water Conference

ACKNOWLEDGMENTS

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- Illinois State Geological Survey
- Illinois State Water Survey
- Iowa Groundwater Association
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- US Geological Survey Illinois Water Science Center

Table of Contents

Program Summary

Tuesday, November 1, 2005

11:00 am to 4:00 pm	**Registration**
1:00 pm to 2:50 pm	Keynote Address and Plenary Session I, Salons A, B, and C
2:50 pm to 3:20 pm	**Break**
3:20 pm to 4:40 pm	Plenary Session I (continued)
5:30 pm to 8:00 pm	**Opening Reception, Salons D, E, and F**

Wednesday, November 2, 2005

7:30 am to 4:00 pm	**Registration**
8:10 am to 9:50 am	Plenary Session II, Salons A, B, and C
9:50 am to 10:20 am	**Break, Sponsored by** ENVIRONMENTAL MONITORING AND TECHNOLOGIES, INC.
10:20 am to 12:00 pm	**Concurrent Sessions** **Salon A** Ground Water Quality In Situ Chemistry **Salons B and C** Ground Water Quantity Aquifer Characterization
12:00 pm to 1:20 pm	**Lunch, Salons D, E, and F**
1:20 pm to 3:00 pm	**Salon A** Ground Water Quality Site Characterization Site Characterization and Remediation **Salons B and C** Ground Water Quantity Aquifer Characterization (cont.) Field Methods—Instrumentation
3:00 pm to 3:30 pm	**Break**
3:30 pm to 5:00 pm	**Salon A** Ground Water Quality Site Characterization and Remediation (cont.) **Salons B and C** Ground Water Quantity Field Methods—Geophysics
5:00 pm to 8:00 pm	**Poster Session and Buffet Dinner** Partially sponsored by Hach Environmental

Thursday, November 3, 2005
Salons D, E and F

8:00 am to 8:10 am	**Invitation to next year's conference**
8:10 am to 9:50 am	Water Supply Sustainability
9:50 am to 10:10 am	Groundwater Recharge
10:10 am to 10:40 am	**Break**
10:40 am to 11:20 am	Arsenic
11:20 am to 12:00 pm	Karst

Program Details

Tuesday, November 1, 2005
Salons A, B and C

11:00 am to 4:40 pm	**Registration**
1:00 pm to 1:10 pm	**Opening Remarks and Welcome** *Beverly L. Herzog* *Illinois State Geological Survey*
1:10 pm to 2:10 pm	**Keynote Address** Our Growing National Water Problem: Is Research the Answer? *Dr. Henry Vaux, Jr.* *University of California, Berkeley*
	Plenary Session I
2:10 pm to 2:30 pm	Nutrients in Ground Water Supplying Domestic Wells within the Glaciated Area of the United States *Kelly Warner and Terri Arnold* *U.S. Geological Survey*
2:30 pm to 2:50 pm	Illinois' Right-to-Know Law (PA 94-314) *Richard Cobb* *Illinois Environmental Protection Agency*
2:50 pm to 3:20 pm	**Break**
	Moderator: Dennis McKenna, Illinois Department of Agriculture
3:20 pm to 3:40 pm	Hazards Associated with Ground Water Sampling and Field Work *Rich Bendula* *Ohio Environmental Protection Agency*
3:40 pm to 4:00 pm	Adapting Regional Aquifer Models to Local Water Supply Problems *Jack Wittman* *WHPA, Inc.*
4:00 pm to 4:20 pm	A Field Investigation of Ground-Water Consumption by Phreatophytes in River Valleys of Kansas *James Butler, Donald Whittemore, and Gerard Kluitenberg* *Kansas Geological Survey, University of Kansas, and Kansas State University*
4:20 pm to 4:40 pm	A Field Investigation of the Influence of Spatial Variability in Hydraulic Properties on Phreatophyte-induced Fluctuations in the Water Table J. *Keller, J. Shea, J. Bauer, J.J. Butler, G.J. Kluitenberg, and D.O. Whittemore* *Kansas Geological Survey and Kansas State University*
5:30 pm to 8:00 pm	**Opening Reception, Salons D, E and F**

Wednesday Morning, November 2, 2005
SALONS A, B, and C

7:30 am to 4:00 pm	**Registration**
8:10 am to 10:20 am	**Plenary Session II** Moderator: Al Wehrmann, Illinois State Water Survey
8:10 am to 9:10 am	The History of Ground Water Modeling *Thomas A. Prickett* *T.A. Prickett & Associates*

Program Details

Wednesday Morning, November 2, 2005

SALONS A, B, and C

9:10 am to 9:50 am — Midwestern America's Dependence on Ground Water: Usage Trends and Forecasts
Kevin B. McCray
National Ground Water Association

9:50 am to 10:20 am — **Break, sponsored by** ENVIRONMENTAL MONITORING AND TECHNOLOGIES, INC.

10:20 am to 12:00 pm — **Concurrent Sessions**

SALON A
Ground Water Quality: In Situ Chemistry
Moderator: Kelly Warner, U.S. Geological Survey

10:20 am to 10:40 am — Volatile Organic Compounds in Ohio's Ground Water: Relationship between Land Use and Sensitive Aquifers
L.D. Slattery, M. W. Slattery, C. Kenah, and M. L. Eggert
Ohio Environmental Protection Agency

10:40 am to 11:00 am — Illinois' Ambient Groundwater Quality Database: Summary of Statewide Trends in Groundwater Quality
Steven Wilson, Brian Kaiser, and Jonathan Foote
Illinois State Water Survey

11:00 am to 11:20 am — Illinois' Ambient Community Water System: Groundwater Monitoring Network Results and Analysis
Joseph Konczyk and Amy Zimmer
Illinois Environmental Protection Agency

11:20 am to 11:40 am — Increasing Dissolved Solids Contents in Shallow Aquifers in the Chicago Metropolitan Area
Walton R. Kelly and Steven Wilson
Illinois State Water Survey

11:40 am to 12:00 pm — Effect of Land Usage on Groundwater Quality
Hue-Hwa Hwang, Samuel V. Panno, and Keith C. Hackley
Illinois State Geological Survey

SALONS B and C
Ground Water Quantity: Aquifer Characterization
Moderator: Don Keefer, Illinois State Geological Survey

10:20 am to 10:40 am — Identifying Models for the Heterogeneity of Hydraulic Conductivity in Fractured Aquifers
Pablo A. Cello, D.D. Walker, A.J. Valocchi, and B. Loftis
University of Illinois, Illinois State Water Survey, and National Center for Supercomputing Applications

10:40 am to 11:00 am — Hydrogeologic Characterization of the Galena-Platteville Dolomite in North-Central Illinois
Dean W. Ekberg
Northern Illinois University

11:00 am to 11:20 am — Methods Used for Preliminary Baseline Hydrogeologic Unit Mapping Using Readily Available Data
Kurt O. Thomsen, Janet L. Agnoletti, and Connie L. Pokorny
Barrington Area Council of Governments

Program Details

SALONS B and C
Ground Water Quantity: Aquifer Characterization (continued)

11:20 am to 11:40 am — A Database of Hydraulic Conductivity Values for Near Surface Materials in Kane County, Illinois: Experience in Mining Data from a State EPA
John Sieving
Illinois State Geological Survey

11:40 am to 12:00 pm — Shallow Aquifer Potentiometric Mapping in Kane County, Illinois
Randy Locke
Illinois State Water Survey

12:00 pm to 1:20 pm — **Lunch, Salons D, E, and F**

Wednesday Afternoon, November 2, 2005
Concurrent Sessions

SALON A
Ground Water Quality: Site Characterization
Moderator: Walt Kelly, Illinois State Water Survey

1:20 pm to 1:40 pm — WITHDRAWN A Cross-Site Comparison of Methods Used for Hydrogeologic Characterization of the Galena-Platteville Aquifer in Illinois and Wisconsin, with Examples from Selected Superfund Sites
Robert T. Kay and Patrick C. Mills
U.S. Geological Survey

1:40 pm to 2:00 pm — Three-dimensional Numerical Modeling of a Paired Drainage Site at Ford County, Illinois
Yue Feng, Albert J. Valocchi, and Robert J. Hudson
University of Illinois

2:00 pm to 2:20 pm — Simulation of Redox Conditions within a Complex Groundwater Flow Field in a Glacial Setting
D. T. Feinstein, M. A. Thomas, and R. Bellini
U.S. Geological Survey, Wisconsin Water Science Center, U.S. Geological Survey, Ohio Water Science Center, Dipartimento di Scienze dell' Ambiente e del Territorio, Universita di Milano-Bicocca, Italy

2:20 pm to 2:40 pm — Long Term Groundwater Monitoring Optimization: Facing the Real World Challenges
Meghna Babbar and Barbara Minsker
University of Illinois

2:40 pm to 3:00 pm — Questions and Discussion

3:00 pm to 3:30 pm — **Break**

Ground Water Quality: Site Characterization and Remediation
Moderator: Steve Benton, Illinois State Geological Survey

3:30 pm to 3:50 pm — Long-term Potential of Chitin Fermentation Products to Stimulate the Complete Reduction of Chlorinated Solvents
Geraldine C. Barnuevo, Charles J. Werth, Robert A. Sanford
University of Illinois at Urbana-Champaign

3:50 pm to 4:10 pm — The HMSI Monitoring System: A Tool for Optimal and Effective Performance Monitoring Demonstrated at an Atlantic Richfield Site
Barbara Minsker, Matt Zavislak, Charles Davis, and Dennis Beckmann
Hazard Management Systems, Inc., Environmetrics & Statistics Limited, Atlantic Richfield

4:10 pm to 4:30 pm	Determining Degradation Rates for Monitored Natural Attenuation of Chlorinated Compounds in Ground Water *Christopher Everts and Anthony Wlodarski* *MACTEC, Engineering & Consulting, Inc.*
4:30 pm to 5:00 pm	Questions and Discussion

SALONS B AND C
Ground Water Quantity: Aquifer Characterization (continued)
Moderator: Dave Larson, Illinois State Geological Survey

1:20 pm to 1:40 pm	Using Geostatistical Methods to Map Subsurface Sand and Till within Illinoian Glacial Deposits of Kane and Champaign Counties, Illinois *Donald A. Keefer and Sarah Rittenhouse* *Illinois State Geological Survey*
1:40 pm to 2:00 pm	Is There Flow through Till? Evidence from Regional Groundwater Flow Models *George Roadcap* *Illinois State Water Survey*
2:00 pm to 2:20 pm	Unconsolidated Aquifers of the Metro East Region: Madison, St. Clair, and Monroe Counties, Illinois *Edward C. Smith, David A. Grimley, Andrew C. Phillips, and Robert C. Vaiden* *Illinois State Geological Survey*

Ground Water Quantity: Field Methods—Instrumentation
Moderator: Dave Larson, Illinois State Geological Survey

2:20 pm to 2:40 pm	WITHDRAWN Introducing Hydrogeology with a Water Level Calculator *Solomon Isiorho and Zachary Long* *Indiana University-Purdue University Ft. Wayne*
2:40 pm to 3:00 pm	High Resolution Ground Water Velocity Monitoring Using Multi-Level Point Velocity Probes *Michael A. McGlashan, J.F. Devlin, and G. Tsoflias* *University of Kansas*
3:00 pm to 3:30 pm	**Break**

Ground Water Quantity: Field Methods—Geophysics
Moderator: John Jansen, Aquifer Science and Technology

3:30 pm to 3:50 pm	Practical Application of Geophysical Mapping for Groundwater Resource Exploration *Gregory B. Byer* *Mundell & Associates, Inc.*
3:50 pm to 4:10 pm	Downhole, Natural-Gamma Logging in Support of Geologic Mapping and Hydrogeologic Investigations in Northeastern Illinois *Christopher J. Stohr, Andrew J. Stumpf, Barbara J. Stiff, Drew Walgren, and Nakhil Sonie* *Illinois State Geological Survey*
4:10 pm to 4:30 pm	Identification of Filled Sinkholes Using Ground-Penetrating Radar (GPR) *Philip J. Carpenter and Dean Ekberg* *Northern Illinois University*
4:30 pm to 5:00 pm	Questions and Discussion

Wednesday Evening, November 2, 2005

POSTER SESSION

SALONS D, E, and F

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Government Data Posters

Hydrogeologic Information Available through the ISGS Web Site
Richard Rice, Illinois State Geological Survey

Development of the ISWS Groundwater Databases for Staff Accessibility and the Web
Jonathan Foote, Steven Wilson, and H. Allen Wehrmann
Illinois State Water Survey

Indiana's Ground-Water Maps and Publications Available Online
Gregory P. Schrader, Glenn E. Grove, and Randal D. Maier
Indiana Department of Natural Resources

New Digital Aquifers Systems Maps for Indiana
Randal D. Maier, Glenn E. Grove, and Gregory P. Schrader
Indiana Department of Natural Resources

New Map of the Surficial Geology of the Lorain and Put-in-Bay 30 X 60 Minute Quadrangles, Ohio
E.M. Swinford, R.R. Pavey, G.E. Larsen, and K.E. Vorbau
Ohio Department of Natural Resources

Educating Ohio's General Public about Source Water Protection
Kristy Hunt, Barbara Lubberger, Diane Canttrell, and Jeanne Russell
Ohio Environmental Protection Agency
Ohio Department of Natural Resources

Research Posters

Continuous Pulse Testing for Estimating Aquifer Parameters
Brett Engard and Carl McElwee
University of Kansas

Long-Term Stewardship Program Update for Argonne National Laboratory, Argonne, Illinois
R. E. Piorkowski, Argonne National Laboratory

Water Quality Characteristics and Contaminants in the Rural Karst-Dominated Spring Mill Lake Watershed, Southern Indiana
Nancy R. Hasenmueller, Mark A. Buehler, Noel C. Krothe, John B. Comer, Tracy D. Branam, Margaret V. Ennis, Ronald T. Smith, Dianna D. Zamani, Leghanne Hahn, and James P. Rybarczyk
Indiana Geological Survey, Indiana University, Indiana Department of Health, Purdue University, and Ball State University

Spatial and Temporal Variability in Streambed Fluxes in an Agricultural Watershed, Leary Weber Ditch, Indiana
Hedeff I. Essaid, John T. Wilson, and Nancy T. Baker
U. S. Geological Survey

The Chemistry of an Arsenic Anomaly Detected in Ground Water Associated with a Confined Feeding Operation in Daviess County, Indiana
Ronald T. Smith, Indiana Geological Survey

Soil Moisture and Saturation: Implications for Determining Jurisdictional Wetland Hydrology
Steven E. Benton, Geoffrey E. Pociask, and Bonnie J. Robinson
Illinois State Geological Survey

Program Details

Thursday Morning, November 3, 2005

SALONS D and E
Ground Water Quantity: Water Supply Sustainability

	Moderator: George Roadcap, Illinois State Water Survey
8:10 am to 8:30 am	The Sustainable Use of Groundwater in Southeastern Wisconsin: A Window of Opportunity *John Jansen* *Aquifer Science and Technology*
8:30 am to 8:50 am	Historic Water Resource Use in Coles County, Illinois *Kathleen M. Bower* *Eastern Illinois University*
8:50 am to 9:10 am	Collector Well Design Using Analytic Elements and Predictive Analysis *Dave Dahlstrom and Vern Rash* *WHPA, Inc. and Des Moines Water Works*
9:10 am to 9:30 am	Statewide Mapping of the Estimated Yield from Glacial Aquifers in Michigan *David P. Lusch, Howard W. Reeves, and Steve A. Miller* *Michigan State University and U.S. Geological Survey*
9:30 am to 9:50 am	Computer-aided Estimation of Ground Water Recharge and Discharge Using GIS and a Pattern Recognition Procedure *Yu-Feng Lin, Jihua Wang, Randy Hunt, Albert Valocchi, and Ximing Cai* *Illinois State Water Survey, University of Illinois, and U.S. Geological Survey*
9:50 am to 10:10 am	Groundwater Recharge: An Illinois Perspective *Edward Mehnert* *Illinois State Geological Survey*
10:10 am to 10:40 pm	**Break**
	Moderator: Pat Mills, U.S. Geological Survey

Ground Water Quality: Arsenic

10:40 am to 11:00 am	Arsenic Geochemistry Associated with a Former Gravel Pit *John McInnes, L.P.G, Matt Dagon, L.P.G., and Shawn Ghosh, PhD, CPG* *SECOR International Incorporated and VECTREN Company*
11:00 am to 11:20 am	Arsenic Speciation and Geochemistry in Central Illinois Groundwater *Thomas Holm, Walton R. Kelly, George Roadcap, and Jon Talbott* *Illinois State Water Survey and Waste Management Research Center*

Ground Water Quality: Karst

11:20 am to 11:40 am	Fate of 17**$**-estradiol ($E_2$) in Water and Sediment-Pore Water from Cave Streams *Eric W. Peterson* *Illinois State University*
11:40 am to 12:00 pm	Bacterial Quality of Groundwater in the Karst Region of Southwestern Illinois *Walton R. Kelly, Samuel V. Panno, Keith C. Hackley, Ivan G. Krapac, and C. Pius Weibel* *Illinois State Water Survey and Illinois State Geological Survey*

ABSTRACTS

Keynote

Our Growing National Water Problem: Is Research the Answer?

Dr. Henry Vaux, Jr.
University of California, Berkeley

A future water crisis in the United States is unlikely to materialize as a monolithic catastrophe that threatens the health and/or livelihood of millions. Rather, it will arise as a growing sum of hundreds and perhaps thousands of problems at regional and local scales throughout the nation. Effective action to deal with the mounting number of these problems may well depend on availability of science upon which management regimes and strategies can be based. Evidence shows that the levels of national spending on water resources research, when adjusted for inflation, are now about the same as they were in the 1970s. The type and quantity of research that will be needed to address current and future water problems are unlikely to be adequate if no action is taken at the federal levels. Water resources problems do not fall logically within the purview of a single federal agency but are fragmented among nearly 20 agencies. The present state of uncoordinated and mission driven water resources research agendas within the federal government will have to change if future water problems are to be solved in a timely and effective fashion.

A well coordinated national research agenda should be balanced between basic research and research applied to water problems; it should be conceived in a broad systems context and reflect the inherent interdisciplinarity of water research; and it should be adaptive and acknowledge uncertainty. The research portfolio should consist of projects that are appropriate for the federal level; have a high expected value; are of national significance; fill knowledge gaps; and complement the overall research portfolio. There is an urgent need to establish a process for regularly reviewing and revising the national water research agenda. The reviews should ensure that the agenda is balanced with respect to time scale, focus, source of expertise and source of problem statement. The current topical array of water research is out of balance with respect to current water management priorities. $70 million dollars should be invested in research focused on institutional topics and to challenges and changes in water use. These funds should either be reallocated from within the existing annual federal investment of $700 million and added to that investment.

There are several options available for coordinating the national water research enterprise. Existing federal organizations in the White House Office of Science and Technology Policy might be used. Another option would be to empanel an independent board with broad representation from the range of stakeholders in water development and management. A third option would entail the establishment of a formal advisory body to make recommendations to the Office of Management and Budget. Coordinating the federal water resources research enterprise will not be a simple matter but failure to do so will sentence the nation to a future which will be far more difficult than it needs to be.

Nutrients in Ground Water Supplying Domestic Wells within the Glaciated Area of the United States

Kelly Warner and Terri Arnold
U.S. Geological Survey, Illinois Water Science Center

The unconsolidated material within the glaciated area of the United States is referred to as the glacial aquifer system, and it is the largest principal aquifer in area and ithe most heavily pumped aquifer used for drinking-water supply in the United States. According to a recent U.S. Geological Survey study, the total withdrawals from the glacial aquifer system were 3,560 million gallons per day in 2000, which constitutes almost 5 percent of total withdrawals from all aquifers in the United States. Approximately 45 million people relied on the glacial aquifer system for domestic supply in 2000. The U.S. Geological Survey National Water-Quality Assessment (NAWQA) program began assessing the glacial aquifer system in 1991. A framework for interpreting water quality across the glacial aquifer system has been developed based on two primary characteristics: aquifer intrinsic susceptibility and vulnerability. Water quality in areas of similar intrinsic susceptibility and vulnerability is being compared. In addition, areas of similar water chemistry, based on major ion chemistry data collected from 1991 to 2004, have been delineated within the glacial aquifer system using cluster analysis and principal component analysis.

Drinking-water use in rural agricultural areas, of which an estimated 90 percent is ground water from domestic wells, is most vulnerable to nutrient contamination because of the surrounding agricultural land use. Water-quality data for the glacial aquifer system collected by the NAWQA program include analyses of 469 domestic wells, 99 public water supplies, and 1,116 shallow monitoring wells across the aquifer system extent. Non-parametric survival analysis is being used to compare domestic well-water quality among well types (public and private). The median nitrate concentration (measured as dissolved nitrate and nitrite) in ground water from domestic and public-supply wells is 0.1 mg/L, and 0.2 mg/L, respectively. These median concentrations differ appreciably from the median concentration for the monitoring wells (1.2 mg/L), which assess recently recharged ground water. Comparison of ground water from domestic, public, and monitoring wells to a nitrate screening level of 1, 4, and 10 mg/L show increasing differences by well type with the higher screening levels. Differences in nutrient concentrations and detections by water use, well characteristics, and chemical concentrations are being explored within the context of the framework based on aquifer intrinsic susceptibility and vulnerability.

Illinois' Right-to-Know Law (PA 94-314)

Richard Cobb, P.G.
Illinois Environmental Protection Agency

Gov. Rod Blagojevich signed a bill on July 27, 2005 that requires that Illinois residents be notified if they live near polluted sites and gives state environmental regulators more power to order polluters to clean up the sites.

The law, which goes into effect immediately, requires those responsible for the pollution to pay for both the cleanup of the sites and the cost of notifying residents that they live near polluted sites. It also gives the Illinois Environmental Protection Agency (Illinois EPA) the authority to issue "administrative orders" to compel responsible parties to clean up sites or contain hazardous contaminants. Until now, the Illinois EPA did not have the administrative authority to issue the orders directly, and had to ask the state's attorney general's office to sue or ask for help from federal regulators. This law gives the Illinois EPA the long overdue authority it needs to order polluters to clean up contamination quickly.

The law was prompted in part by the experience of a group of DuPage County homeowners. One of them, Ann Muniz, learned that her well was polluted with cancer-causing chemicals two years after she moved into the area and waited two more years before she and about 750 others were hooked up to pipes carrying treated Lake Michigan water.

The Illinois EPA and the Groundwater Advisory Council will work with the public and other members of the regulated community on how residents should be notified about pollution. The methods could include phone calls, community meetings, door-to-door visits and public service announcements.

Hazards Associated with Ground Water Sampling and Field Work

Rich Bendula
Ohio Environmental Protection Agency

Geologists may encounter significant safety hazards while doing routine field work. Safety hazards at drilling rigs and construction sites range from potentially fatal injuries involving entanglement, electrocution or engulfment to hearing loss and eye injuries. When field work is conducted at unregulated hazardous waste sites OSHA requires completion of a 40 hour safety course and an 8 hour annual refresher course (29 CFR 1910.120), but typical training courses offered tend to focus on hazardous waste characterization and removal and not on geologic investigations. However, OSHA's General Safety and Health Provisions in 29 CFR 1926.21 require the employer to provide job specific safety training. This presentation will provide an overview of potential hazards which field geologists may encounter so they may be able to identify the hazard and either avoid it or use personal protective equipment and/or engineering controls to eliminate exposure. Employers who provide job specific safety training can meet the requirements for OSHA's annual 8 hour refresher training.

Adapting Regional Aquifer Models to Local Water Supply Problems

Jack Wittman, Ph.D., CGWP
WHPA, Inc.

In many areas of the country the USGS and various state water agencies have spent years developing regional aquifer models to evaluate the overall characteristics of groundwater systems. The USGS reviewed existing well logs, drilled new wells and developed regional models to use in the Regional Aquifer-Systems Analysis program that ran from 1978 through 1996. The purpose of this effort was "to define the regional geohydrology and establish a framework of background information on geology, hydrology, and geochemistry of the Nation's important aquifer systems." While the purpose of these USGS regional models was to consider the very large scale question of flows, the coarse scale of the analysis was necessary to reach any conclusions about the system.

Problems arise when hydrogeologists attempt to adapt these regional investigations to relatively local problems. This presentation will explore how regional models can be refined to address local problems of well field siting, capture zone delineation, and consideration of surface-groundwater interaction. The examples include use of regional models from Illinois, Idaho, Missouri, and Ohio to solve local problems faced by state agencies and local water purveyors. Problems of spatial scale, data management, predictive uncertainty, and institutional infrastructure are considered.

A Field Investigation of Ground-Water Consumption by Phreatophytes in River Valleys of Kansas

James Butler[1], Donald Whittemore[2], and Gerard Kluitenberg[3]
[1]Kansas Geological Survey, [2]University of Kansas, and [3]Kansas State University

Low streamflows are an increasing problem in central and western Kansas. Ground-water consumption by phreatophytes is often invoked as a factor contributing to these low flows. However, estimation of the amount of ground-water consumed by phreatophytes is difficult in the narrow riparian corridors common to the High Plains. A multidisciplinary research effort is underway to improve methods for quantifying phreatophyte water consumption in such settings. Currently, this research is focused on two sites: the Larned Research Site (LRS) along the Arkansas River in central Kansas, and the Ashland Research Site (ARS) along the Cimarron River in southwest Kansas. The LRS is in an area of native riparian vegetation (cottonwood, willow, and mulberry), while the ARS is dominated by invasive species (salt cedar and Russian olive). At both sites, wells screened across the water table have been emplaced at different locations within the riparian zone and equipped with submersible pressure sensors. Neutron-probe access tubes have been installed to assess changes of moisture content above the water table. In addition, meteorological variables are measured at a weather station at each site. Sap-flow, porometry, and stream-stage data have also been collected at the LRS, and phreatophyte inventories have been performed at both sites. This presentation will focus on use of diurnal changes and multi-day trends in the water table to gain insight into and to estimate the rate of ground-water consumption by phreatophytes. Three years of data reveal that the LRS is an area in which the native vegetation is experiencing significant stress as the water table drops in response to regional pumping. The ARS is the site of a salt-cedar removal project, so an approach for estimating the ground-water savings obtained through phreatophyte control efforts will also be discussed.

A Field Investigation of the Influence of Spatial Variability in Hydraulic Properties on Phreatophyte-induced Fluctuations in the Water Table

J. Keller[1], J. Shea[1], J. Bauer[1], J.J. Butler[1], G.J., Kluitenberg[2], and D.O. Whittemore [1]
[1]Kansas Geological Survey and [2]Kansas State University

A number of studies have shown the connection between ground-water consumption by phreatophytes and diurnal water-table fluctuations in riparian zones in semi-arid and arid regions. An ongoing research project is assessing how the information embedded in these fluctuations can be utilized to learn more about phreatophyte water use in conditions common to the High Plains. Spatial variability in the magnitude of the fluctuations is not solely a function of biological factors; heterogeneity in hydraulic conductivity and specific yield may also play an important role. Two field sites have been established to investigate this and related issues. The Larned Research Site (LRS) is located along the Arkansas River in central Kansas and is underlain by a coarse sand and gravel aquifer. The Ashland Research Site (ARS) is located along the Cimarron River in southwest Kansas and is underlain by finer sands and silts. At both sites, well networks have been installed and lithologic variations have been evaluated using direct-push electrical conductivity logging and sediment samples. Spatial variability in hydraulic conductivity is being assessed using slug tests performed at existing wells. At the LRS, spatial variability in specific yield (total drainable porosity) is being estimated using an in-situ method based on changes in soil moisture accompanying changes in the position of the water table (Skaggs et al., 1978). This approach may not be applicable at the ARS because of the finer-grained nature of the media, the higher salinity in the vadose zone, and the shallower depth to water there. In that case, specific yield (readily available) will be determined through collection of sediment samples and laboratory analyses. Once the spatial variability in hydraulic conductivity and specific yield has been estimated, the primary factors controlling the observed variations in the water-table fluctuations within and between these sites can be identified.

The History of Ground Water Modeling

Thomas A. Prickett
T.A. Prickett & Associates

Models have been used for decades to study, analyze, and forecast the response and impact of groundwater systems due to changes in both natural and manmade conditions. Models were developed over the years by devising a large number of techniques for both deriving and then solving the equations of flow and mass transport that we deal with almost everyday in our professional careers.

This presentation discusses most of characteristics of the important types of groundwater models that have been used in the profession over the past 150 years. The most popular models range from the ordinary sand tank, to the large group of mechanical and electric analogs, then on into the use of pure mathematical and numerical representations of aquifer systems solved with a digital computer.

This presentation includes about 55 images of the vast majority of the important groundwater modeling techniques. The models are generally presented in order of the dates of use by hydrologists in the groundwater profession. Descriptions of model characteristics, advantages, and disadvantages are given. No integral signs or differential equations are shown.

An important aspect of the history of model development was, and still is, the development of electronic equipment, the digital computer, and the software that is used to drive the model. A section of this presentation is thus devoted to some of the growing pains related to electronics, special laboratory setups, and the positive impacts of standardization of both equipment and methodology.

Today, groundwater models are basic tools of the trade and almost every serious groundwater hydrologist is capable of using them. The concluding remarks of the presentation offer some of my opinionated reasons why we find ourselves with the present day models that we work with.

Midwestern[1] America's Dependence on Ground Water: Usage Trends and Forecasts

Kevin B. McCray, CAE
National Ground Water Association

Ground water is crucial to Midwestern America's people and the region's economic vitality. Since 1970, Midwestern ground water use has increased nearly 61 percent in total gallons extracted annually. Estimated extractions in 2000 totaled 19.1 billion gallons per day.

Selected market segments have long dominated ground water usage patterns, particularly agricultural irrigation, as well as public water supply withdrawals. Agricultural irrigation in the Midwestern states accounts for nearly 23 percent of all U.S. ground water usage, and uses 13.2 billion gallons a day. Ground water supplied to public water systems, almost 3.2 billon gallons daily, is distributed by 9,044 community water systems, as well as by tens of thousands of non-community public entities. Individual household water well systems have remained stable as a share of private housing starts in the region during the years between 1990 and 2005, while rural populations likely to rely upon these systems have declined only one percent in the five year period between 1995 and 2000, although the number of gallons of ground water extracted for this market segment increased about four percent. Other ground water end-use market segments, such as commercial and industrial uses, aquaculture, thermoelectric power generation, and mining, are relatively insignificant–less than about a combined 1.2 billon gallons per day - in comparison to irrigation and public drinking water supply.

Various socio-economic issues lead to inter- and intra-regional competition for ground water resources. The individual household water well system market has become constricted by urban growth, as well as by rural open space preservation movements. Competing demands from agricultural users, as well as urban users creates tension and will likely cause a need for new paradigms from society, government, and from science.

[1]The author defines the Midwest as: Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Nebraska, North Dakota, and South Dakota.

Volatile Organic Compounds in Ohio's Ground Water: Relationship between Land Use and Sensitive Aquifers

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Volatile Organic Compounds have been regularly monitored in treated water from Ohio's Public Water Systems (PWS) since the promulgation of the National Primary Drinking Water Regulations Phase II rule in January, 1991. Review of this data set includes analysis of some 50,000 VOC samples from approximately 1,900 PWSs. Untreated ground water in Ohio has been monitored since the mid 1980s through the Ambient Ground Water Monitoring Program [Ambient] and currently comprises approximately 1,300 VOC analyses from 228 sites. Approximately 85% of the Ambient sites are PWSs, with the remaining sites being industrial or residential wells. A reporting level of 0.5 ug/L has been in consistent use since the early 1990s across both programs. The VOC data sets have been filtered using confidence criteria set forth by Ohio EPA Source Water Assessment Program's Susceptibility Analysis. Less than 10% of the PWSs have confirmed ground water VOC impacts. More than 90% of this subset of PWSs are located within a sensitive aquifer setting (such as buried valleys or thin glacial tills over bedrock). Comparing these systems to the 2000 census data shows that most of the PWSs with VOC impacts are located in urban areas of low population density, attributed to control by source distribution. Solvent and petroleum compounds were the most frequently detected VOCs in the PWS data set. Chloroform was the most frequently detected compound in the Ambient data set (~20% of the sites), followed by solvents and petroleum compounds. The source for chloroform in untreated water is most probably from recharge of treated water or well disinfection, and almost 90% of these sites are also located within a sensitive aquifer setting.

Illinois' Ambient Groundwater Quality Database: Summary of Statewide Trends in Groundwater Quality

Steven Wilson, Brian Kaiser, and Jonathan Foote
Illinois State Water Survey

The Center for Groundwater Science at the Illinois State Water Survey (ISWS) maintains groundwater-related water-quality data to provide basic information to the general public and to support applied groundwater research activities. These data, which include more than 60,000 samples dating back to the 1890's, have been integrated into a comprehensive database for desktop access and GIS mapping.

The ISWS Public Service Laboratory analyzes groundwater samples in support of research activities at the ISWS as well as a free service for citizens of Illinois. In addition to these data, groundwater-quality data are collected for ongoing research projects where samples are analyzed by outside laboratories, and also provided to the ISWS from other agencies, including the Illinois EPA and the Illinois Department of Public Health. The IEPA has a structured program to collect ambient groundwater samples from municipal wells in Illinois. They provide these data to the ISWS and those data are an integral part of the ISWS groundwater quality database as well.

In addition to providing these data to the public upon request and sharing data with governmental agencies and interests, the ISWS is in the process of conducting a statewide analysis of ambient groundwater quality conditions and trends based on these data. The results of that effort to date, including statewide constituent maps, will be presented.

Illinois' Ambient Community Water System: Groundwater Monitoring Network Results and Analysis

Joseph Konczyk and Amy Zimmer
Illinois Environmental Protection Agency

According to Section 305(b) of the “Clean Water Act” (a generic name that refers collectively to the Federal Water Pollution Control Act of 1972, the Clean Water Act of 1977, and subsequent amendments) and guidance provided by the United States Environmental Protection Agency (U.S. EPA), each state must report to the U.S. Congress and the U.S. EPA on the quality of the surface and groundwater resources of the state. This report, commonly referred to as the “305(b) report,” must be provided in written form every two years, whereas, in alternate years each state may submit an electronic database to meet the reporting requirement. In the 305(b) report, states must also explain how they determined the resource quality of the waters of the state in terms of the degree to which predefined beneficial uses (i.e., designated uses) of those waters are attained (i.e., supported). Also in the 305(b) report, when any designated use for any waterbody is not fully supported (i.e., impaired), the state must report potential reasons (causes and sources) for the impairment

To this end, chemical and biological data were collected for surface water and groundwater resources, throughout the state, to determine if impairments exist. The groundwater data were collected via groundwater-quality monitoring programs including the Ambient Network of Community Water Supply Wells (CWS Network), Pesticide Monitoring Subnetwork of the CWS Network, Rotating Monitoring Network, and Dedicated Pesticide Monitoring Well Network. After analyses of these data, results and other facility information were entered into U.S. EPA Safe Drinking Water Information Systems (SDWIS).

To date, the Illinois EPA concentrated its reporting on analytes that have a Groundwater Quality Standard (GWQS) and could be attributed to anthropogenic causes. These analytes include volatile organic compounds (VOC)s, synthetic organic compounds (SOC)s with a GWQS and Nitrate.

However, for the 2006 305(b) report the Illinois EPA will draw on the historical data obtained from the CWS Network(s) and compare these wells to the total active CWS wells in the state. By expanding our constituent list to include several inorganic contaminants (IOC)s, it is our intention that a baseline (background) concentration for the selected IOCs can be established for CWS wells in the state and the CWS Network of wells. It is the intention that the IOC data will also be used to compare IOCs to aquifer type and depth.

Increasing Dissolved Solids Contents in Shallow Aquifers in the Chicago Metropolitan Area

Walton R. Kelly and Steven Wilson
Illinois State Water Survey

The Chicago metropolitan area is one of the most rapidly expanding metropolitan areas in the USA, with a projected population increase of greater than 20% by 2020. Water use increased about 27% from 1980 to 1992 and demand is expected to continue to grow as the population of the region increases. The principal sources of water in the area, Lake Michigan and deep bedrock aquifers, are being used at their legislated and sustainable limits, respectively. The main sources of water that will be used to meet the increases in water demand are the shallow bedrock and overlying sand and gravel aquifers.

Historical data and recent sampling suggest that urbanization is degrading shallow groundwater quality in the Chicago region. Recent sampling in Kane County indicates that groundwater quality in the eastern urban corridor is significantly worse than in the rest of the county. In another study, temporal changes in water quality in shallow unconfined aquifers are being evaluated using archived and published data. Several hundred shallow (< 200 ft) municipal wells have been periodically sampled in northeastern Illinois in the last 25 years, and some of these have been sampled for decades before that. Concentrations of total dissolved solids and several of the major ions, especially chloride, have increased in the last 25 years, especially in the shallowest wells (< 100 ft). Over 80% of these wells had positive trends for chloride concentrations, with rates varying between 0.1 and 21.1 mg/L/yr, with a median value of 1.2 mg/L/yr. The increase in chloride concentrations began in the 1960s, when road salt began being used in large amounts. The increases in chloride concentrations are most pronounced in the counties west of Chicago, where land use changes are most rapid and aquifer material is closer to the land surface.

Effect of Land Usage on Groundwater Quality

Hue-Hwa Hwang, Samuel V. Panno, and Keith C. Hackley
Illinois State Geological Survey

McHenry County has one of the fastest growing populations in Illinois. The majority of water supplies in the county come from shallow sand and gravel aquifers. Historical groundwater quality records indicated that thirteen percent of shallow wells in the county contained nitrate concentrations greater than 10 mg-N/L. The goals of this study were to determine the change of groundwater quality during the last few decades, to assess the effect of land use on groundwater quality, and to identify the sources of nitrate in McHenry County. Temporal analysis of groundwater records revealed that total dissolved solids, chloride (Cl^-), and nitrate (NO_3^-) concentrations in groundwater have increased since the mid 1960s, indicating deterioration of groundwater quality. This timing coincided with that of population growth in the county and the onset of artificial fertilizer and road salt use. Spatial analysis indicated that shallower wells (less than 100ft) had a greater percentage of elevated Cl^- and NO_3^- concentrations than deeper wells, suggesting a near-surface source. Land use maps combined with NO_3^- data revealed that high NO_3^- concentrations were found in croplands. An aquifer sensitivity map showed a strong correlation between large nitrate concentrations and areas with greatest leaching potential. We collected thirty groundwater samples from different areas of the county for chemical and isotope analysis between 2002 and 2003. Urban samples showed the greatest Cl^- and Na^+ concentration. The greatest NO_3^- concentration was found in rural samples and samples collected adjacent to livestock facilities. Nitrate isotope data indicated that fertilizer and soil nitrogen are the predominant sources of nitrate in shallow groundwater in McHenry County, regardless of the environment. This may be due to the dominance of croplands surrounding municipalities and livestock facilities in the county.

A Cross-Site Comparison of Methods Used for Hydrogeologic Characterization of the Galena-Platteville Aquifer in Illinois and Wisconsin, with Examples from Selected Superfund Sites

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The effectiveness of 28 methods used to characterize the fractured Galena-Platteville aquifer at eight sites in northern Illinois and Wisconsin is evaluated. Analysis of government databases, previous investigations, topographic maps, aerial photographs, and outcrops was essential to understanding the hydrogeology in the area to be investigated. The effectiveness of surface-geophysical methods depended on site geology. Lithologic logging provided essential information for site characterization. Cores were used for stratigraphy and geotechnical analysis. Natural-gamma logging helped identify the effect of lithology on the location of secondary- permeability features. Caliper logging identified large secondary-permeability features. Neutron logs identified trends in matrix porosity. Acoustic-televiewer logs identified numerous secondary-permeability features and their orientation. Borehole-camera logs also identified a number of secondary-permeability features. Borehole ground-penetrating radar identified lithologic and secondary-permeability features. However, the accuracy and completeness of this method is uncertain. Single-point-resistance, density, and normal resistivity logs were of limited use.

Water-level and water-quality data identified flow directions and indicated the horizontal and vertical distribution of aquifer permeability and the depth of the permeable features. Temperature, spontaneous potential, and fluid-resistivity logging identified few secondary-permeability features at some sites and several features at others. Flowmeter logging was the most effective geophysical method for characterizing secondary-permeability features.

Aquifer tests provided insight into the permeability distribution, identified hydraulically interconnected features, the presence of heterogeneity and anisotropy, and determined effective porosity. Aquifer heterogeneity prevented calculation of accurate hydraulic properties from some tests.

Different methods, such as flowmeter logging and slug testing, occasionally produced different interpretations. Aquifer characterization improved with an increase in the number of data points, the period of data collection, and the number of methods used.

Three-dimensional Numerical Modeling of a Paired Drainage Site at Ford County, Illinois

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A three-dimensional finite difference model developed at the University of Illinois was applied to a paired tile drainage site at Ford County, Illinois. This site consists of conventional and managed systems, and tile discharge and nitrate concentration have been continuously monitored by USGS and USDA from June 2001 to September 2004. The field data indicate that the managed system can effectively reduce the nitrate load in its tile outflow as compared to the managed system. Our numerical results are consistent with the field observations and suggest that the reduced nitrate load could be due to lateral flow from the managed plot to the conventional plot during controlled flow periods. By integrating various hydrological processes within this three-dimensional model, time-varying subsurface flow paths around the tile systems can be visualized to enhance our knowledge about the impact of land topography, tile layout and soil properties upon subsurface residence time. The efficiency and accuracy of our model was verified through comparison with a fully-coupled finite element model developed at the University of Waterloo, Canada. The comparison shows that our model takes less CPU time, and thus suits the need for long-term tile drainage simulation that is often required in agriculture practices.

Simulation of Redox Conditions within a Complex Groundwater Flow Field in a Glacial Setting

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This paper describes a modeling approach for studying how redox conditions evolve under the influence of a complex groundwater flow field in a glacial valley-fill aquifer system. The distribution of redox conditions is of interest because it affects the susceptibility of an aquifer to contaminants such as arsenic. The flow system under study, located in the Susquehanna Valley, is typical of shallow and deep glacial aquifers in the eastern and midwestern United States, consisting of outwash and ice-contact deposits separated by lacustrine deposits. The juxtaposition of materials with different hydraulic conductivities, and the influence of surface-water discharge areas and pumping wells, produces a complex velocity field. For this study the MODFLOW-MT3D-RT3D suite of codes has been applied to the glacial setting to test the interplay of flow patterns, sources of electron donors (reactive organic carbon or pyrite), and availability of electron acceptors (dissolved oxygen, nitrate, ferric iron, sulfate, and carbon dioxide). The approach incorporates a simple geochemical model based on the assumptions that redox reactions are approximately first-order with respect to the electron donors and sequential with respect to electron acceptors. Estimates of electron acceptor concentrations in recharge were based on water-quality data from USGS NAWQA program. Hypothetical electron donor sources were simulated as wetlands, lacustrine deposits, and pyrite-rich horizons in different parts of the flow system. The model simulates the degree to which reduced waters circulate away from areas of active redox reactions. Results indicate that local sources can influence the chemistry of aquifer systems at a regional scale, and, thereby, can give rise to relatively widespread reducing conditions. The model simulations show how pumping wells, by changing the flow system and inducing water from surface-water bodies, change the natural distribution of redox conditions, and, consequently, change the susceptibility of the aquifer to mobilization of constituents such as arsenic.

[Key words: redox conditions, transport reaction modeling, RT3D, aquifer susceptibility]

Long Term Groundwater Monitoring Optimization: Facing the Real World Challenges

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Monitoring of groundwater systems is an established practice that aims to address the issues related to groundwater contamination and its environmental consequences. The annual costs in maintaining such long term monitoring (LTM) programs at sites can, however, soar within a wide range of thousands of dollars to millions of dollars. (National Research Council, 1999). Optimization of existing LTM programs has the potential to play a vital role in improving their efficiency and enabling substantial cost savings by eliminating redundant data.

Optimizing LTM programs can involve ad-hoc decision rules or mathematical optimization. Mathematical optimization provides a more thorough search of alternative monitoring plans, but requires objectives and constraints of the monitoring program to be represented in mathematical terms. In the real world, an accurate and comprehensive quantitative representation of all relevant objectives and constraints can be a very challenging task and often is not possible because of their subjective nature. In our work we are developing a user-friendly and interactive optimization system that addresses these issues in a practical approach. In this system, the decision makers and site experts participate in the ongoing optimization process by ranking interim designs. The interactive methodology was used to solve the LTM problem at a site in Michigan for Atlantic Richfield Corporation. The results illustrated the benefits of coupling human interaction with computer search for identifying acceptable monitoring plans.

Long-term Potential of Chitin Fermentation Products to Stimulate the Complete Reduction of Chlorinated Solvents

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The ability of chitin fermentation products to support dechlorination of trichloroethene (TCE) was evaluated in a continuous-flow laboratory column system; the first column was packed with a chitin/sand mixture, and the remaining five columns were packed with dolomite-rich sediments from a contaminated site. The columns were inoculated with an enrichment culture (capable of reducing TCE to ethene) at the beginning of the study, and after 190 days of operation. The retention time in the column system was 28 days based on a tracer test. The columns were fed with groundwater at a flow rate of 0.3 ml/h, and TCE spiked water at a flow of 0.02 ml/h was mixed with the groundwater after the chitin column. TCE concentrations fed to the column system were varied between 30 and 900 mM over a period of nine months.

Chitin fermentation occurred in three stages, the first with a half-life of 8 days, the second with 28 days, and the third with 88 days. The first chitin column maintained sufficient electron donating capacity to degrade all of the influent TCE for 190 days; at this point the chitin was replaced. Initial TCE degradation products were primarily cis-dichloroethene and vinyl-chloride. Ethene production was initially sporadic, and represented only a small fraction of TCE degradation products. After the second inoculation, ethene production increased, and along with CO_2, represented 100% of the TCE degradation products after 222 days. Our results indicate that chitin is an effective electron donor source for reductive dechlorination because it provides a steady flux of electrons over many continuous months. Our results also indicate that complete reduction to ethene is favorable in a continuous flow system, where chlorinated ethenes are spatially segregated due to their sequential reduction. However, considerable lag times may occur and more than one inoculation may be necessary.

The HMSI Monitoring System: A Tool for Optimal and Effective Performance Monitoring Demonstrated at An Atlantic Richfield Site

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Like many organizations, Atlantic Richfield, a BP-Affiliated Company, incurs significant costs associated with performance monitoring of subsurface remediation sites. The purpose of this project is to evaluate the *HMSI Monitoring System*, a new approach for monitoring optimization, troubleshooting, and proving progress, at an Atlantic Richfield site in New Jersey. The system consists of three integrated components:

Model builder creates geostatistical or analytical models of spatial and/or temporal trends based on historical data. It supports both automated and manual model-fitting approaches.

System optimizer identifies sampling locations and/or frequencies that would be most beneficial for further sampling based on redundant sampling locations and times found in past data. This analysis uses multi-objective genetic algorithms, allowing users to readily identify optimal monitoring tradeoffs.

Because monitoring strategies can be designed based only on historical information, it is essential that new data be evaluated relative to expectations. **Data Tracker** allows users to specify monitoring targets that are consistent with site-wide data quality objectives. These targets can include estimated contaminant mass reductions or contaminant level goals at key locations. **Data Tracker** is then used to automatically evaluate new data and identify significant deviations from the targets. Automated alerts can be issued to notify users that further investigation is required, enabling users to focus their attention where it is most needed.

This talk will introduce these components and demonstrate their effectiveness for improving performance monitoring at an Atlantic Richfield site in New Jersey.

Determining Degradation Rates for Monitored Natural Attenuation of Chlorinated Compounds in Ground Water

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Volatile chlorinated compounds and their degradation products have contaminated an alluvial aquifer at a Superfund site in southwest Michigan. Monitored Natural Attenuation (MNA) was identified as the preferred remediation alternative for the site. An estimate of degradation rates was required to demonstrate that MNA was an effective remedy.

Degradation rates were estimated for a composite of 3- & 4-chloride compounds, 2-chloride compounds, and 1-chloride compounds using historical data (C vs. T) and plume geometry (C vs. T). Calculated degradation rates were then used to model concentrations over time and predict time period needed to complete site remediation. Trends in the ratios of parent and degradation products to total CVOCs were also used as a check on the validity of degradation rates obtained.

Arsenic Geochemistry Associated with a Former Gravel Pit

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A plume of dissolved arsenic was identified down gradient of a former gravel pit located in southern Indiana. The gravel pit was closed during 1968 and subsequently filled with construction/demolition debris. Fill materials vary in thicknesses from 10 to 34 feet. Groundwater was encountered 12 to 19 feet below grade, in contact with the lower 10 feet of fill. Investigation and analysis of the fill material failed to identify a source for the arsenic observed in groundwater.

To understand the origin and potential fate of dissolved arsenic, soil and groundwater samples from a network of monitoring wells surrounding the filled area were analyzed for groundwater quality and geochemical parameters. The analytical results were examined to determine the relationship between the geochemical conditions created by the filed area and the presence of dissolved arsenic (both arsenate and arsenite) in groundwater. Data collected to-date suggest a dependence of elevated arsenic concentrations on reduced conditions downgradient of the filled area.

Soil and groundwater analysis identified excess organic carbon sorbed to sediments immediately downgradient of the filled area. Geochemical analysis of the soil and groundwater suggests that the excess organic material created significant biological oxygen demand which generated an area of reduced, anoxic groundwater. The area of reduced groundwater is enriched in arsenic, conductivity, alkalinity, ammonia, ferrous iron and total manganese, and depleted ferric iron, sulfate and oxygen. These conditions suggest that reductive dissolution of arsenic-containing iron oxides and manganese oxides (coatings on soil particles) is occurring in the native outwash unit downgradient of the filled area. Dissolved organic carbon may be triggering microbial activity that creates a reducing environment transforming the hydrous ferric oxides and other sorbed constituents (e.g., manganese, arsenic) into their soluble forms, resulting in the elevated arsenic concentrations downgradient of the filled area, although concentrations within the filled area are comparable to background conditions.

Arsenic Speciation and Geochemistry in Central Illinois Groundwater

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Arsenic (As) was detected (> 1 mg/L) in 60% of the wells sampled in Champaign County and 75% of the wells in Tazewell County. The spatial distribution of As is complex. Wells with high As (>50 mg/L) were located less than 1 km from wells with low or undetectable As. Most of the As was present as As(III), although most samples had detectable As(V). No methylated species were detected. The As speciation was consistent with measured pH and redox potential values. For all samples with TOC and Fe concentrations below 2 and 1 mg/L, respectively, and detectable sulfate, As concentrations were low or undetectable. Conversely, high As concentrations were associated with organic carbon and iron concentrations above these values and with undetectable sulfate. These facts suggest that the source of As is reduction of iron oxide coatings on sand grains with concomitant release of sorbed As. Sulfate reduction produces FeS, which sorbs As(III) and keeps the dissolved As concentration low. The As concentrations in groundwater are thus related to the availability of organic matter and sulfate.

Fate of 17$-estradiol (E2) in Water and Sediment-Pore Water from Cave Streams

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Elevated levels of natural estrogens have been linked to reproductive and developmental disorders in aquatic species. The primary and most potent steroidal natural estrogen is 17**$**-estradiol (E2), which stimulates the growth and development of the female sex organs in vertebrates. Studies have reported the negative effects of heightened E2 concentrations on several aquatic species, including reproductive disorders, organ failure, and death.

The presence of E2 has been observed in waters of karst systems. During recharge events, measured E2 concentrations in discharging spring waters ranged from 6 ng/L to 66 ng/L, while at baseflow conditions springs have exhibited E2 concentrations at 40 ± 20 ng/L. These E2 concentrations are above a 6.6 ng/L threshold documented to cause reproductive disorders. This work examined whether E2 activity decreased within the water and the sediment-pore water of cave systems.

Analysis of the water samples from two Missouri caves showed E2 concentrations of 34.6 ng/L and 29.8 ng/L . The persistence of E2 in the water was examined in two separate experiments in which the holding temperatures (20 °C vs. 4 °C), bottle type, exposure to light, and filtration were varied. During two extended trials, no statistical difference was observed in the concentration of E2, suggesting that E2 is stable within the water.

Within the sediment-pore water of the two caves, E2 concentrations of 60.9 to 131.2 ng E2 per kg sediment (ng/kg) based upon the moisture content were measured. The fate of E2 was also examined in sediment-pore water in two independent trials. In Trial 1, a significant decrease in E2 was noted over the 29 days of the experiment. However, in Trial 2, no change in E2 concentration was observed. The results indicate that E2 is relatively stable in cave stream water and may persist in the sediment.

Bacterial Quality of Groundwater in the Karst Region of Southwestern Illinois

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Ivan G. Krapac[2], and C. Pius Weibel[2]
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Samples were collected from nine springs, one cave, and 47 domestic wells located in the karst region of southwestern Illinois to determine the bacterial quality of the groundwater. The springs, cave stream, and many of the wells were sampled seasonally. Analytes included indicator bacteria (total and fecal coliform, fecal enterococci, and total aerobic bacteria) and inorganic chemistry. Bacterial species were also isolated from samples.

Bacterial quality for the springs was poor, with high levels of fecal bacteria. The bacterial quality of the main channel of the cave stream was also poor, but the quality of streams in side passages was generally better and the quality of ceiling seeps in the cave better still. Well water quality was generally better than the springs or cave, but fecal bacteria were detected in almost 40% of the wells sampled, although at much lower concentrations than in the spring water samples. Shallow wells tended to have poor water quality. There were no correlations for either spring or well samples between concentrations of the bacterial indicators and water chemistry, including NO_3-N, chloride, and DOC, and no significant seasonal variations were found.

More than 20 genera or species of bacteria were isolated from the samples, including five indicative of fecal contamination, including *Escherichia coli* and several *Enterococcus* species. More than 70% of the spring samples contained at least three of these species. Of the other genera/species isolated from the springs, soil-type bacteria were common. *Aeromonas hydrophila*, which is commonly associated with cold-blooded vertebrates, was found in most of the spring and cave stream samples and a few well samples. This species may be a good indicator of conduit systems which contain an air-water interface, are connected to the surface at some point, and are large enough to provide amphibian habitats.

Identifying Models for the Heterogeneity of Hydraulic Conductivity in Fractured Aquifers

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Projected growth of the population in northeastern Illinois is expected to greatly increase dependence on use of groundwater from the fractured dolomite aquifers found in this region. Responsible management of these aquifers requires field characterization studies and modeling analyses to estimate the impact of pumping and the fate of contaminants. However, characterization and analysis of fractured rock aquifers is complicated by their highly heterogeneous nature; where traditional approaches to interpreting aquifer tests fail because they assume idealized flow geometries. An alternative approach to interpreting aquifer tests is the Generalized Radial Flow (GRF) approach, which infers the geometry of groundwater flow via an additional parameter the flow dimension, an additional inferred parameter, which that describes how the effective flow area changes with the radius of investigation. Previous studies have shown that the apparent flow dimension of fractured rocks is often less than the geometry of the formation, suggesting that groundwater flow is restricted to a portion of the domain. The hypothesis of our research is that the apparent flow dimension provides valuable information about the spatial variability in the aquifer. To evaluate this hypothesis, we simulate aquifer tests in alternative plausible stochastic models of aquifer heterogeneity in order to identify plausible representations of the spatial distribution of hydraulic conductivity and simulate radial, transient flow to estimate the flow dimension. This is followed with a simulation of a tracer test to evaluate the transport behavior associated with that flow dimension. These simulations are repeated in Monte Carlo fashion to establish the range of flow dimension and tracer test responses corresponding to particular stochastic models of hydraulic conductivity. To achieve the necessary high level of detail, extensive domains, and number of Monte Carlo simulation replicates, the present study uses the TeraGrid, a high-throughput supercomputing resource developed by the National Science Foundation. Preliminary results suggest that a percolation model of heterogeneity produces flow dimensions observed in many systems that the traditional lognormal model cannot.

Hydrogeologic Characterization of the Galena-Platteville Dolomite in North-Central Illinois

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The Galena-Platteville dolomite is present at the bedrock surface over the majority of north-central Illinois. It is comprised of approximately 350 feet of dolomite of mid-Ordovician age. The primary structure in the area is the Wisconsin Arch, which trends N 30°W and runs through the middle of north-central Illinois. There are three fractures sets present in the bedrock, two near-vertical and one near-horizontal. The near-vertical fracture sets are orthogonal and trend N60°W and N30°E while the near-horizontal fractures form on top of thin clay layers and shale partings and are the result of erosional unloading. A thin mantle of Illinoisan-age glacial drift covers the Galena-Platteville.

North-central Illinois—including Winnebago, Boone, DeKalb, Lee, Ogle, and eastern Stephenson counties—also contains the North-Central Illinois Karst Region, which runs from Dixon to Rockford along both sides of the Rock River. This karst region is actually a glacially-mantled pre-glacial karst area that was rejuvenated by the downcutting of the Rock River. North central Illinois is also host to over a dozen Superfund sites including Byron Johnson, Southeast Rockford, and Belvidere's Parson's Casket sites. Karst increases the risk of groundwater contamination. The Galena-Platteville dolomite is the primary source for domestic water supply in north-central Illinois.

Groundwater flow in the Galena-Platteville is toward the preglacial valleys and is considered part of the Upper Bedrock Aquifer in Illinois. Groundwater flowpaths are controlled by karstification of the vertical and horizontal fracture sets. Recharge occurs primarily through the vertical fractures. Horizontal flow occurs through the bedding plane fractures, mainly along the tops of the thin clay layers or shale laminae. A double porosity flow regime exists in the Galena-Platteville. Primary flow occurs through the solutionally-enlarged fractures with storage taking place primarily in the vuggy porosity and the unkarstified fractures.

Methods Used for Preliminary Baseline Hydrogeologic Unit Mapping Using Readily Available Data

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Over the past decade the public has become more and more concerned with water resources. As a proactive measure, the Barrington Area Council of Governments (BACOG), an association of villages and townships in far northwest suburban Chicago, is currently working on a project to establish water resource baseline conditions in their immediate and surrounding area. Under the direction of BACOG and a professional advisor, a committee of volunteers is conducting much of the work of this water resource initiative using data readily available for little or no cost.

To establish water resource baseline conditions using limited resources, BACOG developed a method to produce baseline hydrogeologic unit maps from readily available borehole log data using GIS querying techniques. Borehole strata descriptions were converted to numerical values by establishing the average hydraulic conductivity of the combined soils making up the stratum of interest. These hydraulic conductivity values were then used to assign each stratum to a hydrogeologic unit based on typical ranges of hydraulic conductivity for aquifers, aquitards and aquicludes. In this manner, the well log data were queried to describe the shallow aquifer system. The bedrock surface, basal aquifer and overlying stratigraphy were described. Aquifers, aquitards and aquicludes overlying the bedrock were defined and preliminary interrelationships were established. Analysis of the resulting information produced cross-sections in areas of interest and identification of potential recharge areas.

A Database of Hydraulic Conductivity Values for Near Surface Materials in Kane County, Illinois: Experience in Mining Data from a State EPA

John Sieving
Illinois State Geological Survey

Many of the mapping products that are of potential use to county and municipal planners for effective water resource management, development, and protection, rely on an accurate portrayal of hydrogeologic properties. However, data are rarely available for areas larger than small, site specific efforts. Wider-scale mapping often must rely on generalized values, such as permeability ranges from soils maps or published hydraulic conductivity ranges based on the dominant lithology. These sources do not give specific values and may or may not represent real world conditions. Collection of detailed data, however, is highly labor and capitol intensive. An often overlooked source for hydrogeologic information is the work of private consultants. Hydrogeologic investigations are commonly required for closure of environmental sites. Illinois law requires that when consultants gather this information, a copy of their report must be submitted to the Illinois Environmental Protection Agency (IEPA). By mining this information from IEPA files, a relational database of hydraulic conductivity values has been assembled for Kane County. Comparisons of screen and sampling intervals with a 3-dimensional geologic model of the county allowed for identification of lithostratigraphic units from which the hydraulic conductivity values were determined. Those data have applications in groundwater resource mapping and groundwater flow modeling.

Shallow Aquifer Potentiometric Mapping in Kane County, Illinois

Randy Locke
Illinois State Water Survey

The Illinois State Water Survey (ISWS) and Illinois State Geological Survey (ISGS) are conducting water resource investigations for Kane County, Illinois, to provide baseline data, analyses, and tools for future water resource analyses. Between May 2002 and August 2003, a network of 1010 private, public, industrial, and commercial wells was assembled that covered an area of 1260 square miles. Synoptic head data, collected in fall 2003, were used to construct interim potentiometric maps of three Quaternary aquifers and a shallow bedrock aquifer. The maps are being used to characterize regional groundwater flow, identify areas of groundwater recharge and discharge, determine regional effects of groundwater withdrawals, and provide a baseline for comparison with future groundwater conditions. The maps will also help development of a conceptual model of groundwater flow and numerical flow models for a wide range of analyses, including aquifer development scenarios.

Interim results corroborate that Marengo Ridge, an extensive glacial moraine, and the Fox River have strong influences on regional groundwater movement in Kane County. Groundwater flow west of the Fox River is predominantly to the south and east. East of the Fox River, flow is to the south and west. Shallow groundwater withdrawals in Kane County, estimated at 6.5 billion gallons in 2003, have lowered heads locally, particularly in east-central and southeastern Kane County.

Analyses of head similarity among lithostratigraphic units identified areas of potential aquifer connections. To refine these analyses, aquifer concurrence and predicted thicknesses of intervening clay-rich deposits will be evaluated. Nomenclature used to describe the aquifers of Kane County should be reevaluated to address vertical and horizontal aquifer continuity. After the conceptual hydrostratigraphy has evolved, interim potentiometric maps will be updated and released in the final report in 2007.

Using Geostatistical Methods to Map Subsurface Sand and Till within Illinoian Glacial Deposits of Kane and Champaign Counties, Illinois

Donald A. Keefer and Sarah Rittenhouse
Illinois State Geological Survey

Geologists at the Illinois State Geological Survey have developed a computerized 3-D geologic map of deposits for Kane County in northeastern Illinois. Seven lithostratigraphic units were defined within the unconsolidated Quaternary and Holocene deposits. The 3-D map was developed by mapping the top and bottom surfaces of each lithostratigraphic unit using computer interpolation software. One of the oldest Quaternary formations in the county is a complex succession of Illinoian age glacial tills and sand and gravels called the Glasford Formation. Wells penetrating the Glasford are too sparse to reliably map the tops and bottoms of the various sand and till members, so we chose to model the sediment distribution using a geostatistical approach that did not rely on surface maps. This approach first involved classifying the materials within the Glasford Formation as either sand or till. These sand-till data were then analyzed to identify patterns in sand thickness and extent at various locations within the county. This analysis showed that sand occurred more frequently and that individual sand deposits were thicker and more continuous horizontally over bedrock valleys than over bedrock upland areas. To reliably model these distinct sand distributions, the county was divided into 2 zones: areas over bedrock valleys, and areas over bedrock uplands. Indicator semivariograms were developed, using observed data characteristics and insight gained from the geologic conceptual model, to describe the variations in sand frequency, thickness and horizontal continuity within these two zones. The semivariograms were used in a geostatistical interpolation technique called sequential indicator simulation to create 50 different yet equally-probable 3-D maps of sand and till distribution. All of the 50 maps were constructed so that they matched the observed data values and honored the three criteria that we used to define geologic reasonableness: the frequency, thickness and horizontal extent of the sand deposits as described by the semivariograms. The 50 maps were sorted based on the total amount of sand they contained, and one map was selected as the most representative with respect to the geologic conceptual model. This map was inserted into the 3-D map of the remaining deposits to represent the Glasford Formation.

Is There Flow through Till?
Evidence from Regional Groundwater Flow Models

George Roadcap
Illinois State Water Survey

Quantifying the amount of groundwater flow through thick sequences of glacial till is a difficult but important task for aquifer resource planning and management. Construction of groundwater flow models can help this task by aggregating the flow through a till layer over a large area and balancing it against the increase in regional flow in an underlying aquifer. A model of the buried sand and gravel Mahomet Aquifer in central Illinois shows that in areas with large vertical gradients, only a small percentage of the water entering the aquifer comes through the overlying till. Almost all of the water enters the aquifer through scattered interconnections with the sands of the overlying formations. Away from these connections the head difference across a till layer between the Mahomet Aquifer and the overlying sands increases to over 120 feet, suggesting an extremely low till permeability. As more of the complex geometry of the upper sand is mapped and incorporated into the model, the calibration improves, and less water is required to flow through the glacial tills to maintain the proper mass balance in the aquifer. In Kane County, Illinois, where large vertical gradients between buried sand aquifers do not exist over large areas, the groundwater flow model is much less sensitive to changes in the permeability of the till. This insensitivity could lead to an over-prediction of the amount of flow through overlying till units and an overestimate of the amount of water available for future groundwater development.

Unconsolidated Aquifers of the Metro East Region: Madison, St. Clair, and Monroe Counties, Illinois

Edward C. Smith, David A. Grimley, Andrew C. Phillips, and Robert C. Vaiden
Illinois State Geological Survey

Sand and gravel aquifers of glacial and post-glacial origin in three southwestern Illinois counties, Madison, Monroe and St. Clair, are being studied as part of an ongoing regional evaluation of groundwater resources. Regional mapping is being conducted at small scale (1:100,000). Concurrently, a statewide, large scale (1:24,000) quadrangle mapping program is also being conducted.

Thick sand and gravel underlie the Mississippi River floodplain. The Mississippi River Valley aquifer is a source of groundwater to high-yielding, large-capacity water wells. On the uplands to the east, shallow and relatively discontinuous sand and gravel deposits are found underneath modern stream valleys and within buried bedrock valleys. Here, the sand and gravel aquifers, until recently, have been poorly delineated and considered poor potential aquifers. Recent mapping has identified areas where these sand and gravel aquifers may be more continuous and suitable for low yielding water wells. Within the buried bedrock valleys in the western uplands, toward the Mississippi River, sand and gravel deposits are relatively discontinuous. Bedrock valleys in the east have thin, though more continuous, sand and gravel.

To better understand the geology and hydrology of a portion of the mapping area, a study of post-glacial sediments is underway in an abandoned meander channel of the Mississippi River in Madison County. This study could provide a basis for the examination of similar depositional sequences throughout the broad Mississippi River floodplain of southwestern Illinois. The valley fill sequence of the study area has proven to be more varied than previously interpreted from logs of borings in the area. Multiple thin, fine-grained layers are present within the upper 30 feet of the alluvial sequence and have been found as deep as 50 feet below land surface in some locations. The underlying sand layers are highly variable in texture. In several borings, gravels were only encountered just overlying the bedrock surface.

Introducing Hydrogeology with a Water Level Calculator

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Field methods and hands-on experience are good ways of introducing students to hydrogeology. Using a well field located on campus, we measured the water levels and collected limited water chemistry on a semi-regular basis for more than six months. We analyzed the water level field data in order to evaluate the relationship between the water levels in four wells in our study area. A plot of the average depth below the ground level versus average water level in each well was made. A linear regression equation was derived from the best fit line and its inverse used to write a program (water calculator) that will take either type of data as an input, and will return the resulting value of the other type of data. This water calculator can then be used to simulate the water level in any drilled well within the study area. Once the simulated water level has been verified in the field, the calculator could then be used to predict water levels in any well within the study area.

The water calculator interface consists of two sides. On the left side of the interface is an area for data input, which would be the known piece of data. A simple text field is used to allow the user to input the data value (which will halt the program if the inputted value is a non-numerical value, or out of range). A drop down "combo box" allows the user to select which type of data to be entered. The proper equation is then selected to find the resulting type of data, based on the selection the user has made in the combo box. After the input has been entered, a press of the "Calculate" button will make the calculations. The numerical results, as well as a short description of what the resulting output represents, are then printed on labels on the right side of the interface, under the "Output" section. Also displayed is a graphical representation of what the inputted and outputted data represent, including the pipe, ground level, and internal water level. This visual depiction should help the user better understand what the numerical inputs and outputs really represent. This program would help students in understanding the relationship between well depth and well water levels and thus help in a key concept of hydrogeology.

High Resolution Ground Water Velocity Monitoring Using Multi-Level Point Velocity Probes

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University of Kansas

Groundwater velocity is an important parameter governing the transport of contaminants to a point of concern. Accurate groundwater velocities are therefore necessary to aid characterization of the contaminated aquifer, for remediation strategies and risk analyses. A novel method of measuring groundwater velocity was first introduced by Di Biasi (1999), and further improved in field conditions by Labaky (2004). Flow is measured at an *in situ* Point Velocity Probe (PVP) by conducting a mini-tracer test along the surface of the cylindrical probe. An electrically conductive tracer is released from an injection port and carried around the circumference of the probe to two electrical resistivity detectors at known distances from the release point. Groundwater velocity is determined based on the arrival times of the saline tracer at the detectors.

The work presented here introduces the use of multi-level PVPs for high-resolution monitoring of groundwater velocity changes during bacterial growth at the Borden test site, Ontario, Canada. Installation of *in situ* probes allows an accurate evaluation of the changes in groundwater velocity to be conducted. Twenty velocity probes were constructed and grouped in five multi-level velocity probe stems spaced 0.3m apart. Each stem consists of four PVPs spaced 0.6m vertically, monitoring a depth range from 1.5 to 4m below surface. These stems were jetted 5m down into the aquifer, down gradient of the biofilm growth area, to provide groundwater velocity profiles across the aquifer. Series of data are recorded at several time periods for the duration of the experiment in order to monitor any changes over time of groundwater velocity across the point of interest in the aquifer. The probes therefore act as an independent means of verifying the results of other hydrogeologic and geophysical methods.

Practical Application of Geophysical Mapping for Groundwater Resource Exploration

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Mundell & Associates, Inc.

Many inland communities and businesses solely rely on the continued availability of groundwater to sustain and support population growth and new development. Although the Great Lakes Region generally experiences plentiful precipitation throughout the year, many communities were founded in localities where potential groundwater production is limited by geologic factors. Vast areas are covered by glacial drift, which is often dominated by glacial till, a material that is generally unsuitable for water supply due to poor water quality and yield. In these locations the alternative source of groundwater is fractured bedrock, and in fact many locations are able to utilize fractured carbonate or sandstone aquifers. However, some communities are underlain by both glacial till and non-aquifer bedrock such as shale or siltstone beneath the till. These communities must search for isolated, coarse-grained water laid glacial outwash deposits, and due to the complexities of the glacial depositional environment, the occurrences of these sand and gravel deposits are difficult to ascertain. Test drilling to find them can be cost-prohibitive, and geophysical exploration is a logical, cost-effective exploratory supplement prior to test drilling. To support this notion, several recent case histories are presented where terrain conductivity and 2-dimensional resistivity have been used to tackle this difficult problem in cooperation with municipal engineers and drilling contractors. These examples illustrate the effectiveness and resulting broad understanding and acceptance of these methods, and demonstrate the potential future applicability of geophysics for groundwater exploration.

Downhole, Natural-Gamma Logging in Support of Geologic Mapping and Hydrogeologic Investigations in Northeastern Illinois

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Illinois State Geological Survey

Natural gamma-ray logs are becoming an important source of semi-quantitative geologic data for improving the understanding of the regional and local glacial geology and its hydrogeological interpretation, particularly in areas of Illinois having thick glacial drift, complex stratigraphy, and few geological exposures. In metropolitan Chicago this information is especially needed as the demand for water from near-surface drift aquifers increases in order to supplement water supplies from bedrock and surface reservoirs. To accommodate the need for collection of detailed data, new water wells are being logged using downhole gamma-ray probes and drilling cuttings collected and described. These data are compiled and archived in a database for use in GIS analysis and 3-D modeling of the geology.

For detailed 3-D geologic mapping, gamma logs are compared with continuous core, drill cuttings, and laboratory data to correlate log patterns with sediment characteristics. As relationships are developed, logs can be used to 1) interpret variability and consistency within units, 2) discriminate between sediments of similar texture, 3) identify gradational and abrupt contacts, and 4) distinguish sedimentary facies that comprise the complex glacial stratigraphy of Illinois. In boreholes where samples are collected at intermittent intervals during drilling, gamma logs provide a continuous record.

The relationship of gamma measurements to material texture is complex. In general, lower counts per second (cps) are recorded for well-sorted quartzose sands and gravels, limestone and dolomite; relatively higher counts indicate finer material such as lake clays, clay-rich tills and associated ice-contact sediments, and shale. Statistical analyses of gamma measurements of 68 samples show a moderate, direct correlation with texture. Laboratory measurements of potassium and thorium for Wadsworth till show high correlation in the clay fraction.

Identification of Filled Sinkholes Using Ground-Penetrating Radar (GPR)

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Karst aquifers are highly susceptible to contamination, with numerous points of entry for contaminants through recharge features such as sinkholes, swallow holes and soil pipes. These recharge features may be filled or obscured at the surface, requiring the use of geophysical techniques or remote sensing for their identification. This study specifically investigates the use of ground-pentrating radar (GPR) to delineate filled or buried sinkholes to depths of about 10 m.

GPR profiles from two sites in northern Illinois and one in eastern Tennessee were examined. Settlers Cave is a network-type cave of interconnected solutionally-enlarged fractures, located south of Rockford, IL. Ground-penetrating radar (GPR) profiles over Settlers Cave, utilizing 50 and 100 MHz antennas, show strong diffractions over unsaturated caves and karst conduits. A trough-like feature approximately 20 m wide and 3 m deep was also identified in GPR profiles approximately 20 m west of the mapped cave passages. This feature coincides with a small linear depression at the surface. It may represent an elongate filled sinkhole, similar to those observed along the wall of a quarry less than 1 km west of the cave. GPR profiles and two-dimensional electrical resistivity imaging were also performed at the Perry Farm Park in Bourbonnais, IL, where 1 to 4 meters of loess and till overlie karstic Silurian dolomite. Clay-filled sinkholes 2-3 m wide and about 3 m deep strongly attenuated GPR signals, and were sites of anomalously low resistivity. GPR surveys made at two sites near Oak Ridge, TN, show trough-like patterns of radar reflections and diffractions over known and probable filled sinkholes. One trough-like feature almost 45 m wide, and 3.5-5.0 m deep, overlies a hydraulically-active bedrock cavity at 18 m depth. These cases suggest GPR is an effective reconnaissance tool for identifying filled or buried sinkholes in different settings.

The Sustainable Use of Groundwater in Southeastern Wisconsin: A Window of Opportunity

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Aquifer Science and Technology

The sandstone aquifer has traditionally been the major source for municipal groundwater systems in southeastern Wisconsin. Unfortunately, the aquifer has been over pumped for decades. Water levels in sandstone wells in southeastern Wisconsin have been dropping at a rate of 5 to 10 feet per year with over 500 feet of decline from predevelopment conditions. Many sandstone wells exceed the MCL for radium and gross alpha. Several wells have experienced rising salinity over the last 20 years requiring the lower portion of the borehole to be filled in some wells to produce potable water. Great Lakes diversion law prevents serving much of the fastest areas with water from Lake Michigan. Faced with declining head and expensive water treatment, many communities have shifted demand to the shallow aquifer system. While current pumpage amounts to less than 10% of the recharge to the shallow system, concerns over the potential impact on surface water bodies have led to several disputes over siting new high capacity wells in the shallow aquifers.

Modeling conducted with the Southeastern Wisconsin Regional Groundwater Model has shown that heavy pumping in the sandstone aquifer has caused a reversal in the regional gradient and a net change in flow of 6 mgd beneath the Lake Michigan shoreline. Approximately 80% of the sandstone pumpage is coming from capture from the shallow aquifers. The current pattern of water use has been causing impacts to the shallow system for decades, although we are just beginning to recognize this fact.

This new level of understanding of the regional flow system is allowing local planners to choose intelligent compromises from a series of planning alternatives. The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has started a source of supply study to determine the most efficient and sustainable way to provide water to the region. The study will look at a variety of sustainable supply alternatives and evaluate the cost and environmental impact of each alternative. The study will be conducted by SEWRPC with technical assistance from the USGS, the Wisconsin Geological and Natural History Survey, and a consulting engineering company.

Historic Water Resource Use in Coles County, Illinois

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Geologic resources and features attract humans to a geographic location and allow communities to grow and develop. Without a continuing source of resources, especially water, communities may decline. As populations grow and technology changes, the amount of water needed and the source of the water changes. If the demand for water increases beyond the available supply, communities need to develop other water sources, such as imported water from other regions, usually at greater expense. This has been documented in arid regions and populated regions of the United States. It may be beginning even in areas of the Midwest with low population density.

Coles County, Illinois contains typical rural and small urban communities of the Midwest. Public water supply has historically come from surface water and limited groundwater supplies. The county's land use is predominantly agricultural. The two largest communities are Charleston and Mattoon. Mattoon has an industry-based economy that developed with the railroads in the 1800's. Charleston is the county seat and the location of Eastern Illinois University. As the county population grew and industrial demands increased, demand for water supply increased. The historic resources of water show a trend of decreasing reliance on groundwater and increasing use of surface water from man-made reservoirs. Recently, some communities in the county have begun importing water from outside the county. An increase in water supply demand in Coles County is projected for the future; total water use in the county is projected to increase by 80% (2000-2025). Historic and projected information needs to be available to community planners for effectively planning of sustainable usage for the future.

Collector Well Design Using Analytic Elements and Predictive Analysis

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WHPA, Inc. and Des Moines Water Works

A two-well collector well system currently being installed on the Des Moines River north of Des Moines, Iowa was designed using analytic element groundwater models combined with predictive analysis. The goal of the design was to provide a conservative estimate of the productivity of the proposed system.

A regional analytic element groundwater flow model was constructed using ModAEM and calibrated using hydraulic gradient data, hydraulic head data from synoptic water level measurements from a wet period and dry period, drawdown data from two aquifer tests, and baseflow data. Based on the calibrated model, a water supply system consisting of two radial collector wells was estimated to yield 13 million gallons per day (MGD).

The minimum and maximum productivity of the generic two-well system were estimated using predictive analysis to be 9.2 MGD and 16.8 MGD, respectively. A series of well designs were then compared using local analytic element models (TimML) and the regional model. Lateral arm elevations were optimized using the local, multiple-layer models and various arm lengths and orientations were compared using the regional model to maximize the yield of the system under the worst-case condition. The optimal design maximized well capacity and maximized the ratio of surface water to groundwater produced by the system.

Statewide Mapping of the Estimated Yield from Glacial Aquifers in Michigan

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Abstract: A newly compiled glacial landsystem map was combined with information from the *Wellogic* database to produce a quantitative estimate of glacial aquifer yield. The landsystem map provides regional information about where the anticipated transmissivity is low, intermediate, or high. For each well in the *Wellogic* database, an estimated hydraulic conductivity for each stratum was assigned based on glacial landsystem, the primary lithology and any lithologic modifier. An equivalent hydraulic conductivity was calculated for the saturated thickness of each well, defined from the bottom of the well screen, or the top of rock for wells completed in bedrock underlying the glacial deposits, to the reported static water level. Multiplying the equivalent hydraulic conductivity by the saturated thickness produced an estimate of drift transmissivity at each well location. In areas of the State where the glacial deposits are thick, the transmissivity estimate is only based on the upper portion of the glacial package penetrated by water wells and reported on well logs. A simple analytical equation using the transmissivity and saturated thickness for each well and a constant storativity value of 0.001, typical of a leaky-confined aquifer, estimated the pumping rate required to lower the hydraulic head at the well to fifty percent of the available drawdown after 100 days of pumping. This rate was mapped as the estimated yield from the glacial deposits. The estimated-yield point file was segmented within landsystem groups. Each group of points was interpolated using ordinary kriging to generate 1 km^2 grids that were combined into a statewide raster file. The final estimated yield map was overlaid with thin drift areas (<= 30 ft.) and blanked in regions more than 2000 meters away from any well data point.

Computer-aided Estimation of Ground Water Recharge and Discharge using GIS and a Pattern Recognition Procedure

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The management of water resources requires quantifying the interaction between components of the hydrologic cycle, including the rates and variability of recharge and discharge (R/D) to aquifers. These R/D rates define the relationships between groundwater, precipitation, and surface water, and thus can restrict management options for water supply. We are developing a Geographic Information System (GIS) software package to estimate shallow R/D using advanced image processing. The software is programmed in Visual Basic using the ArcObjects environment. This GIS-based software will associate with the existing groundwater modeling code, MODFLOW, and parameter estimation code, PEST, for a linked R/D analysis and calibration. The goal of this research is to provide an efficient R/D estimation tool that allows the user to select variable degrees of zonation. The software is relatively quick to apply and uses readily available hydrogeologic data. During development, the software has been verified using a hypothetical model and will be tested on field sites in Wisconsin which have been well-studied by the USGS. The final version of this software will be applied to ongoing ISWS studies of groundwater in Illinois. The software design is modular, allowing the incorporation of additional R/D estimation methods as they become available. This is a two-year joint research by the Illinois State Water Survey, University of Illinois at Urbana-Champaign and the U.S. Geological Survey (USGS). This project is supported by National Institutes for Water Resources and the USGS.

Groundwater Recharge: An Illinois Perspective

Edward Mehnert
Illinois State Geological Survey

Some researchers say that the sustainability of groundwater supplies depends upon the water recharged, but others claim that sustainability depends upon the discharge that can be captured. In general, the sustainability of groundwater supplies is determined by the water flow through the hydrologic cycle. Precipitation is the ultimate source of water in aquifers. Precipitation infiltrates the soil with some flowing to the water table and recharging groundwater. This groundwater follows local flow paths to discharge to local streams and lakes or regional flow paths to discharge to regional rivers and lakes.

In Illinois, groundwater recharge has been estimated by mass balance, hydrograph separation, groundwater flow modeling, and geochemical analysis. The quantitative estimates of recharge range from 0.14 to 10.7 in/year. A review of these estimates reveals some different definitions of "recharge" and an appreciation for the quality of the estimated values. This review also reminds us that recharge varies in space and time. Recharge varies over space due to different hydrogeologic settings and different positions within the local/regional flow systems. Recharge can also vary over time because variations in precipitation control the quantity of water that can be recharged and variations in groundwater pumpage alter the vertical hydraulic gradient over time.

Hydrogeologic Information Available through the ISGS Web Site

Richard Rice
Illinois State Geological Survey

The Illinois State Geological Survey maintains the ILH2O ArcIMS interactive website, enabling the public to interactively search and display various GIS layers and data tables relevant to hydrogeology and groundwater availability. The user can select layers and tables that display water and related wells, major sand and gravel aquifers, major bedrock aquifers, potential aquifers at a depth of less than 50 feet, bedrock topography, glacial drift thickness, karst areas, digital orthophoto quadrangles, and the USGS topographic map index. Individual well records collected by the ISGS for over 100 years consist of drillers' records for domestic, municipal, industrial, commercial, and irrigation supplies, and also include engineering and stratigraphic borings. Map layers are derived from the ISGS's extensive collection of geologic maps created for resource evaluation and planning on statewide, regional, and local scales.

Through the ILH2O ArcIMS interactive website, the user can select and display multiple layers. This simplifies the use of information from these databases and assists the user in the evaluation of state, regional, and local distribution of aquifers. For example, bedrock topography and drift thickness are useful in statewide and regional screening because some of the most extensive and productive aquifers in the state are located in thick glacial sediments within major buried bedrock valleys. On a local scale, the ILH2O ArcIMS can be used to determine areas where large-diameter or small-diameter wells are more feasible due to the presence or absence of thick glacial drift or if bedrock has groundwater potential. The integration of these data in an easy-to-use format provides individuals, drillers, government agencies, consultants, farmers, and business interests with many of the attributes necessary for assessing groundwater availability.

Development of the ISWS Groundwater Databases for Staff Accessibility and the Web

Jonathan Foote, Steven Wilson, and H. Allen Wehrmann
Illinois State Water Survey

The Center for Groundwater Science at the Illinois State Water Survey maintains groundwater-related databases to provide basic data and information to the general public and to support applied groundwater research activities. Data types include groundwater quality, water use (withdrawals), aquifer hydraulic properties, groundwater levels, and drillers records for private, public, industrial/commercial, and irrigation wells. These data, spanning more than 100 years, are integrated into a SQL-structured relational database. GWInfo, is a VB.net application that has been developed in-house to provide desktop access to these data. GWInfo allows a user to input, view, download, or chart data for a well, in an area, or by project. It allows the user to create data sets in minutes that previously would have taken hours or even days to produce. All data includes spatial coordinates, allowing data to be imported into easily into ArcSDE and ArcIMS.

This new data structure/integration has allowed selected sets of the ISWS data to be connected to the Illinois Environmental Protection Agency's (IEPA) Source Water Assessment and Protection (SWAP) Program ArcIMS site. SWAP-linked data include annual water withdrawals from Illinois community and self-supplied industries, ambient groundwater quality data, and aquifer hydraulic properties data from aquifer tests performed throughout Illinois over the past 50+ years.

GWINFO is currently most useful, however, to the staff at the ISWS. It has streamlined our data entry procedures, provides easy desktop access to data, allows scientists to store and share data from research projects in standard formats, and has built-in web development to view data and graphs as well as to download data. It also contains a custom built laboratory information management system(LIMS) system for the ISWS Public Service Lab that has integrated laboratory and sampling data with the water quality database, and automatically generates reports and QA/QC information for laboratory staff.

Indiana's Ground-Water Maps and Publications Available Online

Gregory P. Schrader, Glenn E. Grove, and Randal D. Maier
Indiana Department of Natural Resources

A survey taken by the Indiana Department of Natural Resources (IDNR), Division of Water (DOW) in 2002 indicated that customers preferred digital groundwater data and e-products to paper maps and reports. In response to this, all new products are offered in digital form.

Since 2003, the primary focus of the DOW's Resource Assessment Section has been to assess ground water availability in Indiana. The resulting products, bedrock and unconsolidated Aquifer Systems maps, are offered online for individual counties as digital images along with the text and accompanying tables. All ArcGIS shapefiles used in creating the final maps are also available. Additionally, all older ground water publications and maps, including Ground-Water Atlases (1964-1977), Ground-Water Bulletins (1945-1993), and Basin Studies (1987-2002) have been scanned and made available online. All online digital products may be downloaded free of charge.

The DOW website, featuring all of the Division of Water's publications related to ground water, has recently been redesigned to allow users to graphically choose an individual county from a map of Indiana or the particular publication series of interest.

http://www.in.gov/dnr/water/ground_water/ground_water_assessment/GWAMaps.html

Future counties scheduled as part of the Aquifer Systems mapping initiative are highlighted and the planned order of completion is also shown as a guide to when new products will become available.

New Digital Aquifers Systems Maps for Indiana

Randal D. Maier, Glenn E. Grove, and Gregory P. Schrader
Indiana Department of Natural Resources

In early 2003 the Resource Assessment Section within the Department of Natural Resources, Division of Water (IDNR/DOW) started production of a new series of aquifer systems maps for the purpose of assessing Indiana's ground water resources. The mapping process is almost completely digital resulting in timely and cost efficient production of the maps as well as providing a product beneficial to a wide range of professionals and the general public. The digital maps (with accompanying text and tables) are available online as digital images and ArcGIS shape files.

Bedrock and unconsolidated aquifer systems (sedimentary packages with similar characteristics and yield potential) are defined and mapped within individual counties in Indiana. The maps also describe characteristics such as geologic materials, range in thickness of the aquifer materials, thickness of confining units as well as analysis of typical well depths, depth to the aquifer resource, static water levels and well yield. Original mapping is done at a scale of 1:24,000 and is intended for use at a scale of 1:48,000. Mapping of the aquifer systems rely heavily on the IDNR/DOW digital water well record database (available online) along with other useful digital information where available (e.g. seismic data, bedrock topography maps, soil surveys, oil and gas wells).

The current mapping initiative is planned for a total of 68 counties (21 finished) to complete areas of the state not previously mapped as part of the IDNR/DOW Basin Studies series. Upon completion, this new map series will provide complete, seamless, and consistent aquifer systems coverage for the entire state.

New Map of the Surficial Geology of the Lorain and Put-in-Bay 30 X 60 Minute Quadrangles, Ohio

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A map depicting the surficial geology of the Lorain and Put-in-Bay 30 x 60 minute (1:100,000-scale) quadrangles has been produced by the Ohio Department of Natural Resources, Division of Geological Survey. Surficial deposits were mapped at 1:24,000 scale for 36 7.5-minute quadrangles, compiled digitally using GIS technology, and converted into a full-color, print-on-demand, 1:100,000-scale, surficial-geology map which includes all or portions of Erie, Huron, Lorain, Lucas, Sandusky, and Seneca Counties in north-central Ohio. Data sources include field mapping, county soil surveys, Ohio Department of Transportation and Ohio EPA boring logs, engineering logs, water-well logs, theses, and published and unpublished geologic and hydrogeologic reports.

Map polygons were attributed using a stack-unit designator that indicates the thickness and stratigraphic sequence of major material units (e.g., till, gravel, sand, silt, and clay), from the surface down to and including the uppermost bedrock unit. Several regional material trends stand out on the map, including large areas of lacustrine clay and silt landward of Lake Erie, the prominence of shallow bedrock paralleling the Lake Erie shoreline, a deltaic sequence deposited during higher levels of water of ancestral Lake Erie, the locally widespread and thick organic and marl deposits, and the expanse of Wisconsinan-age till mantling most of the quadrangles. The map text explains how to read the map, provides lithologic descriptions of mapped glacial and bedrock units, and offers other explanatory information.

A GIS Geodatabase contains spatial information on each polygon and data attributes of the stack units that can be queried on the basis of material types and thickness to quickly create derivative maps. Potential queries for derivative maps might include isolating clay and silt deposits for identification of potential geohazards, identification of sand and gravel deposits for aggregate exploration, or depicting the areas of thick glacial till for the identification of potentially favorable solid-waste disposal sites. Mapping was partially funded by the U.S. Geological Survey, National Cooperative Geological Mapping Program, STATEMAP component.

Educating Ohio's General Public about Source Water Protection

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The Ohio Environmental Protection Agency (OEPA) and Ohio Department of Natural Resources (ODNR) recently received an Ohio Environmental Education Fund grant ($35,171) to develop Source Water Environmental Education Teams (SWEETs). SWEETs will assist Ohioans in understanding and protecting their source water resources. County Soil and Water Conservation Districts, a total of 35 statewide, will be the vehicle for organizing their local water resources partners into regional/county SWEETs.

The SWEET project will: A) Facilitate the general public's access to ground water education resources by developing a statewide delivery system; B) Provide train- the-trainer workshops and local outreach efforts; and C) Ensure the long-term sustainability of the program by establishing mechanisms to support SWEETs and facilitate their ability to communicate on a statewide basis.

ODNR and OEPA staff will prepare SWEETs, through tools and training, to assist Ohio's public water systems with their drinking water source protection planning efforts. SWEETs also will provide source water environmental education outreach at public events (e.g. county fairs, community festivals, municipal meetings, etc.). Provided tools include ground water simulator models, drinking water source assessment reports, and protection area maps. Training will introduce techniques used to design ground water simulator demonstrations around any audience's local water resources. Follow-up training, an organized listserv, and a SWEET Web page will be developed to facilitate communication among teams statewide and work to maintain SWEET project success.

Continuous Pulse Testing for Estimating Aquifer Parameters

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The physical flow of groundwater is typically the dominant factor in contaminant transport. Thus, the need to determine the distribution of hydraulic conductivity (K) may be paramount. Typical methods used to determine K include pumping tests, which give average values over large volumes, and slug tests, which give detailed information near a well. Presented here is a method to determine the ratio of K to specific storage (Ss) between wells. Controlled sinusoidal pressure head fluctuations are introduced into a shallow semi-confined aquifer and the resulting amplitude decay and phase shift are observed at various radial distances and depths. Relative estimates of an average K/Ss between wells can then be determined from the signal attenuation and phase shift at the measured depths. Theory predicts that the phase and the log(Amplitude*%r) will vary linearly with K/Ss and distance (r) from the source well. Pneumatic and injection techniques have been used as sources for pressure pulsing. Line sources equal to the total screen length and point sources isolated by custom bladder packers were used in these experiments. At observation wells whole well response and packed off screen responses were monitored. The fidelity of the observed signal was improved when the water column in the observation well was not allowed to oscillate by being packed off. The pneumatic system would be advantageous at contaminated sites because little equipment decontamination is required and nothing is being introduced or removed from the aquifer. To add larger and more controllable oscillating head pressures, an injection method was developed. Preliminary data suggests that signal propagation may occur over considerable distances and therefore provide average well to well estimates of the spatial distribution of K at various depths.

Long-Term Stewardship Program Update for Argonne National Laboratory, Argonne, Illinois

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The Long-Term Stewardship Program at Argonne National Laboratory was initiated at the conclusion of the Environmental Remediation Program in October 2003. The program consists of ongoing operations, maintenance and groundwater monitoring at four units which previously completed corrective action on the ANL property. Included in the program are the 317/319 Area Groundwater Extraction Systems, the 317/319 Area Phytoremediation Project, the Off-Site groundwater Seeps, and the East Northeast Landfill.

Fifty-nine monitoring wells and 25 extraction wells comprise the IEPA approved groundwater monitoring program at the four units. Operations and Maintenance consists of ensuring performance of the groundwater extraction systems, inspection for integrity of landfill caps, and monitoring phytoremediation plantation. Quarterly sampling entails assessing field parameters, and collecting samples for organics, metals, VOC's and radiological analysis. Data is reported and compared with corresponding Illinois Class I Groundwater Quality Standards (WQS). Reporting of Quarterly activities is accomplished through a detailed report summarizing data, findings and planned activities, and is submitted to IEPA. An annual review of Long-Term Stewardship Activities is also included in the ANL Site Environmental Report. The ANL Annual report is available online for public viewing on the ANL website.

Long-term monitoring is a proactive approach to ensuring the protection of our groundwater resource. Extensive long-term monitoring will continue to provide the necessary information for Argonne and surrounding communities.

Key Words: Groundwater Sampling, Long-Term Monitoring

Water Quality Characteristics and Contaminants in the Rural Karst-Dominated Spring Mill Lake Watershed, Southern Indiana

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The Spring Mill Lake watershed is located in the Mitchell Plateau, a karst area developed on Mississippian carbonates in southern Indiana. Spring Mill Lake is a reservoir built in the late 1930s and is located in Spring Mill State Park. Within the park, ground water from subsurface conduits issues as natural springs and then flows in surface streams to the lake. From 1998 to 2002, surface and subsurface hydrology and water quality were investigated to determine the types and sources of potential contaminants entering the lake.

Water-quality monitoring sites were established at eight locations in Spring Mill State Park. Water samples collected during baseflow and a February 2000 storm event were analyzed for selected cations, anions, and trace elements, selected U.S. Environmental Protection Agency (EPA) primary and secondary drinking water contaminants, nitrogen isotopes, suspended solids, *Escherichia coli*, and pesticides. All the water samples met the EPA drinking water standards for inorganic constituents, except those collected at five sites in August 1999 during a drought. Nitrate nitrogen (NO_3-N) concentrations were highest during baseflow conditions and displayed a dilutional trend during peak flow periods. The NO_3-N concentrations in water samples collected during the 2001 spring fertilizer applications tended to increase from early to late spring. All the $\delta^{15}N$ values were low and are indicative of either an inorganic source or soil organic matter. Storm discharge did contain increased concentrations of total suspended solids; thus, storms are responsible for most of the sediment accumulation in the lake. *E. coli* levels in 24 percent of the samples analyzed contained a Most Probable Number (MPN) greater than 235/100 mL, which is the maximum acceptable level set for recreational waters in Indiana. *E. coli* does appear to be a potential health risk, particularly at Rubble spring. The sources of *E. coli* found at this spring may include barnyard runoff from a horse barn or wastes from a wastewater treatment facility. The pesticides atrazine, metolachlor, acetochlor, and simazine were detected during the spring of 2001. Atrazine, metolachlor, and acetochlor are used to suppress weeds during corn and soybean production. Likely sources of simazine are application to right-of-ways, orchards, and managed forest areas.

Spatial and Temporal Variability in Streambed Fluxes in an Agricultural Watershed, Leary Weber Ditch, Indiana

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The Agricultural Chemicals Topical Study (ACT) of the U.S. Geological Survey's National Water Quality Assessment Program (NAWQA) is studying multiple settings with various agricultural management practices to assess the fate of agricultural contaminants. As part of this effort, surface water - ground water (SW-GW) interactions have been studied in the streambed of the Leary Weber Ditch, a 7.2 km^2 subwatershed within the Sugar Creek Basin, IN. This is an intensively farmed corn and soybean region with poorly permeable surface and subsurface materials, predominantly till with interbedded lenses of outwash. Three methods were used to determine the streambed SW-GW exchanges: point measurements using seepage meters; streamflow measurements at upstream and downstream sites; and one- and two-dimensional modeling of water and heat flow. Hydraulic heads and water temperatures were monitored continuously within piezometer clusters along two transects near the mouth of the subwatershed. Simulation of water and heat flow was used to help interpret the head and temperature observations, and deduce the SW-GW fluxes. SW-GW exchange was influenced by physical heterogeneity below the streambed, specifically the distribution of clay deposits. Water exchange was low through sections of the streambed underlain by clay, with higher flow through the streambed occurring where clay was absent. Model estimates of flux magnitude and direction varied throughout the year. In general, flux was upward through the streambed during the wet part of the year (October-June) with the exception of flood events. Flood events resulted in rapid short-lived reversal of flow direction causing water to flow downward into the streambed. During the dry season (July-September), surface-water was periodically lost to ground water resulting in drying of the ditch. Seepage meter and streamflow measurements support the temperature-based flux estimates. These findings are being used to improve the understanding of the fate of agricultural chemicals in these environments.-

The Chemistry of an Arsenic Anomaly Detected in Ground Water Associated with a Confined Feeding Operation in Daviess County, Indiana

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Indiana Geological Survey

Three groundwater monitoring stations were installed at a confined feeding operation where poultry manure is applied to soils in a highly permeable hydrogeologic setting in southwestern Indiana. Two of the sites are fertilized with manure, while the control site receives commercial fertilizer. Arsenic is consistently found in ground water at a depth of 7 feet at one station whose lithology indicates the presence of organics and manure in its topmost soil horizon. The arsenic concentration at this site often exceeds the Safe Drinking Water Act Maximum Contaminant Level of 10 parts per billion. Arsenic is not detected at the other stations. Because the hydrogeologic setting is similar at all three stations, this arsenic anomaly presents an opportunity to test theories involving the source of the arsenic and the factors that control its mobilization.

Virtually all poultry raised in confined feeding operations are fed organically-bound arsenic in the form of roxarsone or some other commercial coccidiosis preventative. Most of this arsenic is excreted, and the resulting manure ranges up to 75 parts per million arsenic by weight. It is not possible to directly trace the migration of organic arsenicals from the manure because they degrade rapidly once applied to soil. Because the organic arsenicals cannot be traced, indirect methods must be used to determine if the arsenic detected in the ground water originated in manure applied to surface soils. It is also possible that arsenic has been mobilized from subsurface mineral phases, either by nitrate-induced oxidation of arsenopyrite and phosphate phases, or by reduction of arsenic-bearing iron oxides by organic matter. Organic compounds, phosphate, and nitrate in the manure could have caused the arsenic anomaly by enhancing the dissolution of native arsenic from solid phase minerals through chemical or biological processes.

Statistical analyses of water chemistry parameters were used in an attempt to determine the most probable source for the arsenic anomaly. Preliminary analysis of the correlations observed within the data suggest that it is more likely that the arsenic originates from the manure rather than from native minerals.

Soil Moisture and Saturation: Implications for Determining Jurisdictional Wetland Hydrology

Steven E. Benton, Geoffrey E. Pociask, and Bonnie J. Robinson
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Jurisdictional wetland hydrology defines saturation as ground-water to within 30 cm of land surface, or inundation of land surface to a maximum depth of < 3.3 m, for at least 5% of the growing season. Saturation is generally determined by measuring the depth to ground-water in monitoring wells that are screened between 0.3 m and 0.7 m. Our observations from shallow monitoring wells at 3 locations in southern Illinois reveal that water levels respond much faster to precipitation events than would be expected based on published values of soil permeability. This suggests that the published values underestimate the actual permeability. This discrepancy is likely due to the presence of macropores (fissures, fractures, and roots), and soil structure (shape and arrangement of soil peds) which cause unconfined conditions and allow rapid infiltration and saturation in both disturbed and undisturbed soil profiles.

In addition to measuring ground-water levels, we also measured volumetric water content with dielectric soil moisture probes. These data reveal that ground water and volumetric water content respond similarly to the onset of precipitation, but the drying curves for soil moisture show that the soil stays at or near saturation longer than is indicated by water-level data. The factors that likely cause this include, but are not limited to, the primary water source supporting wetland hydrology and the presence of the capillary fringe. The implications are that wetland hydrology may occur for longer periods and over larger areas than is indicated by only measuring water levels in monitoring wells.

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50th Annual
Midwest Ground Water
Conference

Past Host States

2005 Illinois
2004 Indiana
2003 Michigan
2002 North Dakota
2001 Wisconsin
2000 Ohio
1999 Minnesota
1998 Kansas
1997 Iowa
1996 Kentucky
1995 Missouri
1994 North Dakota
1993 Illinois
1992 South Dakota
1991 Indiana
1990 Nebraska
1989 Michigan
1988 Ohio
1987 Wisconsin
1986 Arkansas
1985 Minnesota
1980 Indiana
1979 Minnesota
1978 Missouri
1977 Arkansas
1976 South Dakota
1975 Kansas
1974 Ohio
1973 Illinois
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1969 Kentucky
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1967 Ohio
1966 North Dakota
1965 Minnesota
1964 Illinois
1963 Michigan
1962 Indiana
1961 Iowa
1960 Missouri